GC University Lahore

Taxonomy and Distribution of Giraffids in the Lower Siwaliks of Pakistan

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Taxonomy and Distribution of Giraffids in the Lower Siwaliks of Pakistan

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in
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by

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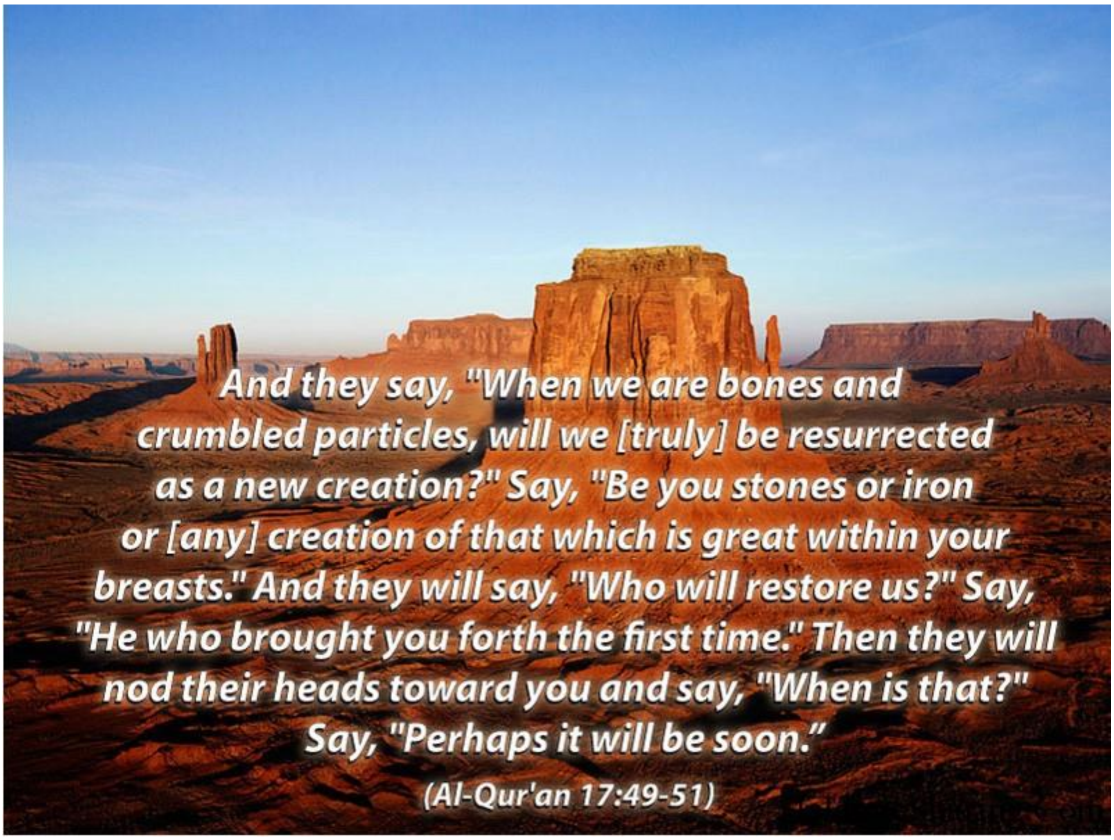
IN THE NAME OF ALLAH, THE MOST BENEFICENT, THE MOST MERCIFUL



THE PROPHET HAZRAT MUHAMMAD (PEACE BE UPON HIM) SAID:

"God, His angels and all those in Heavens and on Earth, even ants in their hills and fish in the water, call down blessings on those who instruct others in beneficial knowledge".

DECLARATION

I, Ms. **Kiran Aftab**, Roll No. **0709-Ph.D.-Z-08**, Student of GC University Lahore in the subject of **Zoology**, Session **2008**, hereby declare that the matter printed in the thesis titled **Taxonomy and Distribution of Giraffids in the Lower Siwaliks of Pakistan** is my own work and has not been printed, published and submitted as research work, thesis or publication in any form in any University, Research Institution etc. in Pakistan or abroad.

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Dated Signature of Deponent

RESEARCH COMPLETION CERTIFICATE

Certified that the research work contained in this thesis titled **Taxonomy and Distribution of Giraffids in the Lower Siwaliks of Pakistan** has been carried out and completed by Ms. **Kiran Aftab,** Roll No. **0709-Ph.D.-Z-08** under my supervision.

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Dated

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Submitted Through

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____
Controller of Examinations
GC University Lahore

DEDICATION

Dedicated to

My Sweetest Son

AMAYED AFROZ

And

MY DEAREST MOTHER

Who is everything,

My consolation in sorrow,

My hope in misery,

My strength in weakness,

The only one,

Who has been a source of love, mercy, sympathy and forgiveness.

ABSTRACT

A detailed systematics of the Lower Siwalik giraffids has been worked out. Seventy two specimens are selected for this research project comprising mandible and maxilla fragments, and isolated upper and lower dentitions. Three species *Progiraffa exigua*, *Giraffokeryx punjabiensis* and *Giraffa priscilla* of the early Siwalik giraffids are identified and discussed here.

The material was collected from thirteen localities of the Lower Siwalik outcrops nearby Jaba, Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial, Chabbar Sayadan, Lava, Phadial, Bhelomar, Parrhewala and Ratial of northern Pakistan. These localities represent the Kamlial Formation and three levels of the Chinji Formation: Jaba (Kamlial Formation), the Lower Chinji (Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial), the Middle Chinji (Chabbar Sayadan, Lava, Phadial) and the Upper Chinji (Bhelomar, Parrhewala and Ratial). The outcrops range in age between 18.3-11.2 Ma.

The *Progiraffa exigua* remains are recovered first time from the Chinji Formation of the Lower Siwaliks, northern Pakistan, extending the range of the species from the Kamlial Formation to the Chinji Formation of the Pakistani Siwaliks. *Giraffokeryx punjabiensis* and *Giraffa priscilla* are common faunal elements in the Middle Miocene of the Siwaliks. They could not survive with large giraffids *Bramatherium* and disappeared before the onset of the Dhok Pathan Formation (ca 10.2 Ma). The faunal correlation of the Lower Siwalik giraffids is discussed. The Lower Siwalik fauna shows similarities to African and Eurasian faunas. The paleoenvironment of the Lower Siwaliks (18.3-11.2 Ma) was wet and humid having extensive forest component and developed grassy lands.

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Kiran Aftab

LIST OF ABBREVIATIONS

Ma	Million years ago
mm/yr	Millimeter per year
ca	Circa
GCUPC	Government College University Paleontological Collection, Lahore, Punjab, Pakistan
PUPC	Punjab University Paleontological Collection, housed in the department of Zoology, Punjab University, Lahore, Pakistan
GSP-S	Geological Survey of Pakistan-Sind Collection, Quetta, Pakistan
GSP-Y	Geological Survey of Pakistan-Harvard University Project, USA
GSP-H	Geological Survey of Pakistan-Howard University Project, USA
GSI	Geological survey of India, Kolkata
AMNH	American Museum of Natural History, New York, USA
DP^2	Second upper deciduous premolar
DP^3	Third upper deciduous premolar
DP^4	Fourth upper deciduous premolar
P^2	Second upper premolar
P^3	Third upper premolar
P^4	Fourth upper premolar
M^1	First upper molar
M^2	Second upper molar
M^3	Third upper molar
I_3	Third lower incisor
P_2	Second lower premolar
P_3	Third lower premolar
P_4	Fourth lower premolar
M_1	First lower molar
M_2	Second lower molar

M_3	Third lower molar
r	Right
l	Left
W/L	Width/Length ratio
mm	millimeter
s	series (more than one)

Chapter 1

INTRODUCTION

Siwalik Hills are famous for its mammalian fossil fauna. Almost all major vertebrate phyla have been recorded from the Siwalik formations. The name "Siwaliks" was developed from the Siwalik Hills in Deharadun, India by Medlicott (1864). Wynne (1879) introduced the same term for similar rocks present in Pakistan. The Siwalik localities were recognized by Baker and Durand in 1836. Later on, Falconer and Cautley (1847) explored many areas of the Siwaliks and gave the first scientific description of the Siwalik fossils in their book "*Fauna Antiqua Sivalensis*". Falconer (1868) referred the presence of petrified and under process bones of man and elephant in his compendium of "*The History of Mughal and Pathan Emperors"*.

About twenty million years old, the Siwalik deposits occurred in thick sequences along the Southern flanks of Himalayas, extending from the Indus River on the north, the Brahmaputra River on the south (Falconer, 1868). Lydekker (1876) reviewed the Falconer and Cautley's work and wrote many articles about the Siwalik fossils in the record of *Geological Survey of India*. Pilgrim (1919) and Pascoe (1920) have tried to explain the history of deposition of the Siwalik Hills. According to these workers, a great river "Siwalik River" flowed northward into the remnants of the Tethys Sea. Simultaneous with the retrieval of the Sea, the ancient river followed it, turning at right angles from its old course. The Siwalik deposits accumulated along the course of the ancient river. That is why from older to younger strata of the Siwaliks, the sediments became more and more coarse denoting the increasing uplift of Himalayas from north to east.

Matthew (1929) critically studied the biostratigraphic position of the Siwalik mammals. The Siwalik Hills are the range of hills to the north-westerly limits of Sub-Himalayas which includes the area between Attock (Pakistan) and Shimla Hills (India) as well as Potwar Plateau of Pakistan (Colbert, 1935). The Potwar Plateau lies between the Sub-Himalayes and Salt Range in Pakistan. Towards east, it extends along the eastern bank of the Jhelum River and towards west the Indus River has a definite boundary.

The Siwalik succession was build up by two major processes i.e. lateral accretion and vertical accretion (Barry *et al*., 2002). The lateral accretion units comprise clay or silt-free sandstone horizons with conglomeratic lenses and gravels. These are formed as a result of lateral migration of rivers charged with sand with point bar deposition. Vertical accretion is achieved by the settling out of the finer grained sediments in the flood plain some distance from the area undergoing lateral accretion. Intercalations of the materials of lateral and vertical accretions results when a river migrates back and forth so quickly that it does not allow the vertical accretion deposits to accumulate or when it completely cannibalized the material of vertical accretion. Clays are formed in the areas where the rivers seldom ran (Pickford, 1988).

The fossiliferous outcrops of the Chinji Formation consist of 70% bright red clays and 30% subordinate ash grey fine to medium grained sandstones. The age of this Formation is from 14.2 to 11.2 Ma (Barry *et al*., 2002; Nanda, 2002, 2008). The Chinji thickness varies from place to place. However, it is estimated from 800 m thick at type locality (near Chinji village) to 2000 m thick in Trans Indus range (Hussain *et al*., 1979; Kafayat Ullah *et al.*, 2006).

The present collection consists of seventy two specimens of the family Giraffidae from the Lower Siwaliks of Pakistan and can be referred to three species of the Middle Miocene giraffids *Progiraffa exigua, Giraffokeryx punjabiensis* and *Giraffa priscilla*. It includes fragments of mandibles and maxilla, and isolated dentitions.

1.1 Studied Sections

The material comes from the thirteen localities of the Lower Siwaliks in northern Pakistan: Jaba, Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial, Chabbar Sayadan, Lava, Phadial, Bhelomar, Parrhewala and Ratial.

1.1.1 Age

These localities represent Kamlial Formation and three levels of the Chinji Formation: Jaba (Kamlial Formation) is 18.3-14.2 Ma in age, the Lower Chinji (Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial) of ca. 14.2-13.2 Ma, the Middle Chinji (Chabbar Sayadan, Lava, Phadial) with estimated age of 13.2-12.2 Ma and the Upper Chinji (Bhelomar, Parrhewala and Ratial) is 12.2-11.2 Ma in age. The Lower Siwalik Formation is assigned an Early to Middle Miocene age from 18.3-11.2 Ma (Barry *et al.*, 2002; Nanda, 2002, 2008).

1.1.2 Geography and geology

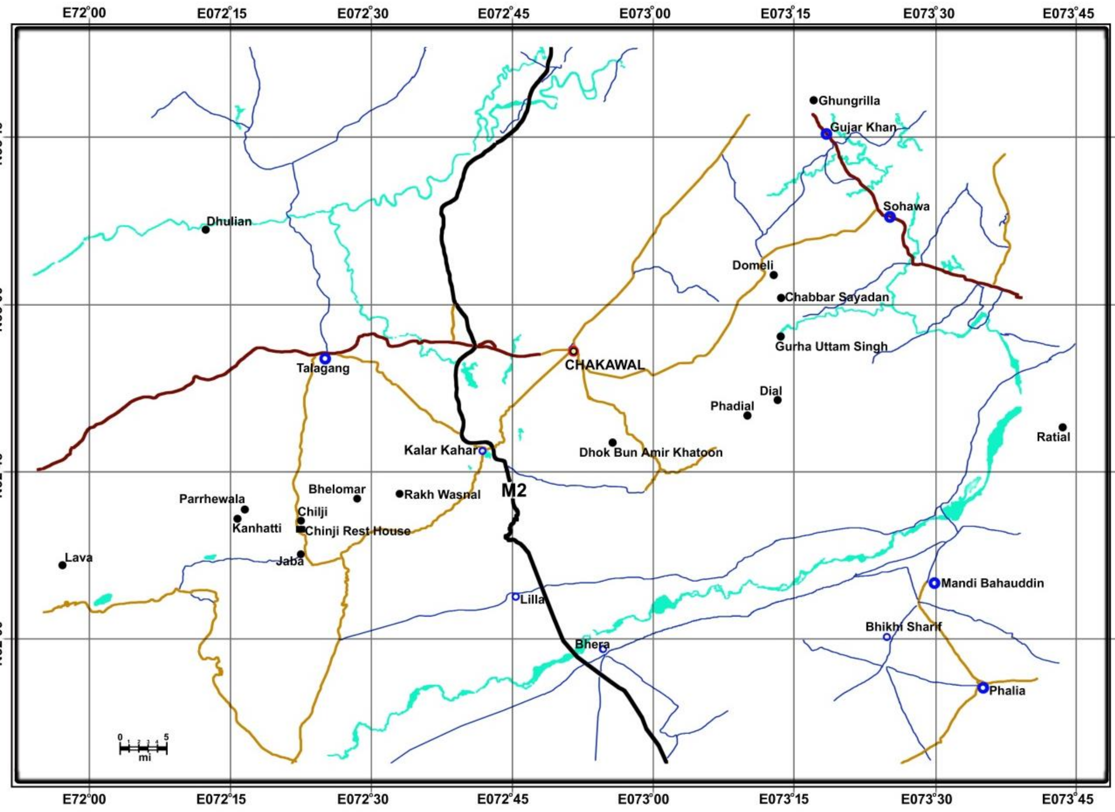


Figure 1.1: The location of Jaba, Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial, Chabbar Sayadan, Lava, Phadial, Bhelomar, Parrhewala and Ratial

in northern Pakistan from where the described material has been found. Boundary dates are from Barry *et al.* (2002) and Nanda (2002, 2008).

Jaba

The Jaba village (Late. 32° 62′ N; Long. 72° 37′ E) is situated on Talagang Sargodha road (Figures 1.1, 1.2). It is approximately 12 km south of the Chinji village. The outcrops of Jaba are Kamlial in age and scantily fossiliferous (Sarwar, 1973). These are sand dominated outcrops with hard, dark, ridge forming sandstones with subordinate mudstones and conglomerates. The sandstones are dark grey to greenish gray, subangular to subrounded and fine to coarse grained interbedded with brick red siltstones. The mudstones are dull reddish and purple, and conglomerates are light red coloured. The sandstones contain abundant mica and dark minerals (Kafayat Ullah *et al.*, 2006). Fossils seem to be more primitive than those from other localities of Lower Siwalik Formation.

Figure 1.2: A typical site of the Jaba village (Kamlial Formation), northern Pakistan.

Chinji Rest House

Chinji Rest House (Late. 32° 39′ N; Long. 72° 22′ E) is located about 3 km south of the Chinji village, the Chakwal district, northern Pakistan (Figures 1.1, 1.3). The outcrops are composed of sandstones and siltstones. The sandstones are bluish grey to brownish grey, whereas the silts vary in color from brownish to yellowish and grayish to tan.

Figure 1.3: A typical site of the Chinji Rest House (Chinji Formation), northern Pakistan.

The sandstone components are dominant over clays and fossils are mostly found in these rocks. The clays are somewhat compact with nodules and are mostly non-fossiliferous. The sediments represent the basal fauna of the Chinji Formation (Barry *et al*., 2002).

Rakh Wasnal

Rakh Wasnal (Late. 32° 43′ N; Long. 72° 33′ E) is located about 4 km east of the Bhelomar village from where Ghabir river takes its northwards turn (Figures 1.1, 1.4). The bright red clays are dominant and richly fossiliferous. The ash gray sandstone layers are usually thin and loose in nature. The outcrops also represent the basal fauna of the Chinji Formation (Sarwar, 1990).

Figure 1.4: A typical site of the Rakh Wasnal (Chinji Formation), northern Pakistan.

Dhok Bun Amir Khatoon

Dhok Bun Amir Khatoon (Lat. 32° 47' N, Long. 72° 55' E) is situated about 50 km northeast of the Chinji stratotype, Chinji Formation (Figures 1.1, 1.5). The outcrops comprise shales, siltstones and sandstones deposited in a fluvial environment, mainly filled by unweathered igneous minerals. The stratigraphic range of the assemblage suggests the age dated between 14.2 and 11.2 Ma area (Cheema, 2003; Khan *et al.*, 2008, 2011).

Figure 1.5: A typical site of the Dhok Bun Amir Khatoon (Chinji Formation), northern Pakistan.

Dhulian

It is a small village of the Chakwal district (Late. 32° 39′ N; Long. 73° 43′ E), situated on the Talgang-Pindigheb road (Figures 1.1, 1.6). The fossiliferous beds extend from half km south of the village. The rocks are chiefly bright red clays containing some amount of gypsum. Clays are interbedded with thin layers of light brown sandstones (Khan *et al.*, 2005).

Figure 1.6: A typical site of the Dhulian village, (Chinji Formation), northern Pakistan.

Ghungrilla

It is a railway station (Late. 33° 00′ N; Long. 73° 22′ E) situated on Lahore-Rawalpindi Railway track (Figures 1.1, 1.7). It is about 45 km away from Jhelum city towards Rawalpindi. About a half km north of the railway station, thick bedding of Lower Chinji sandstones with subordinate red clays may be seen. The fossils are found in the red clay only (Sarwar, 1990).

Figure 1.7: A typical site of the Ghungrilla village (Chinji Formation), northern Pakistan.

Figure 1.8: A typical site of the Dial (Lower Chinji Formation), northern Pakistan.

Dial

Dial (Late. 32° 85′ N; Long. 73° 21′ E) is located on Phadial-Padhri road, Jhelum district (Figures 1.1, 1.8). The Middle to Late Miocene outcrops is located in the south of the village (Sarwar, 1977). The outcrops are composed of bright red clays, brick red shales and grey sandstones. The sandstones are crossbedded and hard.

Chabbar Sayadan

It (Late. 33° 00′ N; Long. 73° 22′ E) is a small village located at about 17 km of Sohawa at the western base of Bakrala ridge (Figures 1.1, 1.9). The outcrops are predominantly red placed on subordinate hard grey sandstones with interbedding narrow beds of siliceous nodules. The majority of fossils are found in claystones. It belongs to the middle part of the Chinji Formation (Sarwar, 1990).

Figure 1.9: A typical site of the Chabbar Sayadan village (Chinji Formation), northern Pakistan.

Lava

The Lava village (Late. 32° 36′ N; Long. 71° 56′ E) is connected with Rawalpindi Mianwali highway and the outcrops are about 11 Km southeast of the village (Figures 1.1, 1.10), comprises grey sandstones, siltstones and reddish shales (Barry *et al*., 2002).

Figure 1.10: A typical site of the Lava village (Chinji Formation), northern Pakistan.

Phadial

Phadial (Late. 32° 83′ N; Long. 73° 16′ E) is a small village of the Jhelum valley. It is located at the northern base of the Salt Range almost 8 km away from Choa Saydan Shah (Figures 1.1, 1.11). The outcrops are consist of red clays with medium to thick bedded soft gray sandstones. It is a Middle Miocene in age and has yielded a number of mammalian groups such as tragulids, giraffids and early suids (Sarwar, 1973).

Figure 1.11: A typical site of the Phadial village (Chinji Formation), northern Pakistan.

Bhelomar

The outcrops of the Bhelomar area (Late. 32° 43′ N; Long. 72° 27′ E) are located at about 1.5 km east of the Bhelomar village (Figures 1.1, 1.12). The outcrops belong to the upper portion of the Chinji Formation. The rocks are low hillocks exposed by the erosion of the upper lying alluvium. The strata comprise typical exposure of the Chinji rocks, i.e. bright red clays with subordinate light grey sandstone. Both the components are equally fossiliferous (Khan *et al*., 2012).

Figure 2.12: A typical site of the Bhelomar village (Chinji Formation), northern Pakistan.

Figure 1.13: A typical site of the Parrhewala (Chinji Formation), northern Pakistan.

Parrhewala

Parrhewala (Late. 32° 41′ N; Long. 72° 16′ E) is a name of a local farm. It is located at about 1 km south east of the Chinji village (Figures 1.1, 1.13). The rocks are predominantly bright red clays with abundant of siliceous nodules forming pseudoconglomerates. The sandstones are dark brown and crossbedded (Sarwar, 1990).

Ratial

Ratial (Late. 33° 04′ N; Long. 73° 53′ E) is a small village located on Jhelum-Rawalpindi railway section, about 10 km from Dina city in the Jhelum district, northern Pakistan (Figures 1.1, 1.14). The Chinji rocks are well expressed bearing Lower Siwalik fauna. Bright red clays are the dominating feature. The outcrops are comprised of brown mudstones interbedded with brownish gray sandstones (Sarwar, 1977).

Figure 1.14: A typical site of the Ratial (Upper Chinji Formation), northern Pakistan.

1.2 Aims of Present Study

The main core of work is to generate new information of the Lower Siwalik giraffids in northern Pakistan.

The lower Siwalik giraffid fauna is compared with the related non Siwalik African and Eurasian faunas.

The chronostratigraphic occurrence and palaeoecology of the Lower Siwalik giraffids are discussed and updated.

Chapter 2

REVIEW OF LITERATURE

The Siwalik Hills are relatively low, having an altitude from 300 to 1200 meter above sea level (Ahmed, 1995). The Hills actually comprise a series of parallel ridges, forming a belt some 13 km or so in width (Colbert, 1935). Fossil record of Pakistan Potwar Plateau is best for the interval from 18 to 6 Ma (Lihoreau *et al*., 2004). These formations have yielded important mammalian fossil fauna represented by various orders such as Primates, Rodentia, Lagomorpha, Carnivora, Proboscidea, Perissodactyla and Artiodactyla (Colbert, 1935; Raza *et al*., 1984; Barry *et al*., 2002). The suborder Ruminantia (order Artiodactyla) is well represented in the Siwaliks from the small tragulid (*Darcotherium minus*) to the large giraffid (*Bramatherium*) (Barry and Flynn, 1989; Khan and Akhtar, 2014a).

Due to its great Palaeontological importance, the Siwaliks fauna has been explored by a numbers of scientists from abroad as well as from Pakistan, such as Cautley (1835), Baker and Durand (1836), Falconer and Cautley (1836, 1849), Falconer (1868), Lydekker (1876, 1878, 1880, 1882, 1883a, b, 1884, 1886, 1887), Wynne (1877), Blanford (1879), Medlicott (1879), Theobald (1881), Middlemiss (1890), Pilgrim (1908, 1910, 1912, 1913, 1914, 1919, 1926, 1932, 1937, 1939), Pinfold (1918), Matthew and Granger (1923), Wadia (1928), Matthew (1929), Cotter (1933), Colbert (1935), De Terra and De Chardin (1936), Lewis (1937), De Terra and Paterson (1939), Hussain (1971), Sarwar (1971, 1973, 1977, 1990), Nanda (1978, 1992), Barry *et al*. (1982, 2002, 2005), Sarwar *et al*. (1986, 1988, 1989), Sarwar and Akhtar (1987, 1989, 1990, 1991), Akhtar (1996, 1998, 2002, 2003), Solounias and Semprebon (2002), Flynn (2003), Lihoreau *et al*. (2004), Khan *et al*. (2005, 2008, 2009, 2010, 2011, 2012), Khan and Farooq (2006), Khan and Akhtar (2007, 2011, 2014b).

2.1 Giraffidae

Artiodactyls originated from Dichobunidae. Animals of this family were present in Holarctic region of Pangaea (North America, Europe and Asia) during the Early Eocene i.e. about 60-55 Ma. Animals of this group were (rabbit-sized) *Diacodexus* which had astragulus (a most characteristic bone in the skeleton, gave very great freedom of motion to the ankle for the flexion and extension of limb). From

Dichobunidae, North American Hypertragulidae evolved about 40 Mya, which gave rise to Leptomerycidae about 35 Mya, from which a successful Artiodactyl group Gelocidae emerged in southerly Eurasia about 25 Mya. Giraffoidea evolved from Gelocidae before the Early Miocene (Colbert, 1935; Janis and Scott, 1987; Gentry and Hooker, 1988).

Superfamily Giraffoidae is presented by the following basic characteristics: unbranched ossicones attached to raised hollow bosses on the frontal bone (Hamilton, 1978). Posterior region of the P_4 separated from the central and anterior regions. Central lingual cuspid strongly developed on P_4 and not joined to the central labial cuspid (Harris *et al*., 2010).Cheek teeth of giraffes are brachyodont to moderately hypsodont, enamel lining is thick and corrugated (Colbert, 1935; Churcher, 1978).

From Giraffoidea, two families originated in Early-Middle Miocene i.e. Climacoceratidae and Giraffidae. In family Climacoceratidae branched assicones on the frontal were present. Climacoceratidae were found in Kavirondo Gulf of Lake Victoria (MacInnes, 1936), in Kenya (Gentry, 1970), in Namibia (Hendey, 1978) and in Africa (Hendey, 1982). Family Giraffidae had unbranched appendages (Singer and Bone, 1960; Hamilton, 1973, 1978). In this family only lower incisors and canines are present, while first premolar is absent. They have very long diastema which separates incisors and canines from cheek teeth.

Singer and Bone (1960) determined the most diagnostic character in giraffes i.e. bilobed lower canine which was present in *Giraffokeryx*, *Hydaspitherium, Sivatherium* (Colbert, 1935), *Samotherium* (Bohlin, 1926), *Palaeotragus* (Rodler and Weithofer, 1890; Borissiak, 1914; Alexejew, 1916), *Giraffa* and *Okapia* (Lankester, 1910). But in these entire genera accessory lobe is larger than anterior lobe (Hamilton, 1978). In the Lower Siwaliks of Pakistan, three subfamilies of Giraffidae are present i.e. Progiraffinae, Giraffokerycinae and Giraffinae. Giraffes and their sister groups i.e. cervids and bovids are closely related to antilocaprids (Hernandez Fernandez and Vrba, 2005).

Fossils of giraffes are well-known in Asia, Europe and Africa (Colbert, 1935; Churcher, 1979; West, 1981; Geraads, 1985). The family Giraffidae includes only two living genera and species i.e. *Giraffa camelopardalis* and *Okapia johnstoni*. Both species are present in Ethopian region (Beaufort, 1951; Solounias *et al*., 2000). *Giraffa camelopardalis* is found in Africa below the Sahara while *Okapia johnstoni* is confined the thick forests of Africa.

2.1.1 Previous Work on Giraffids

Giraffidae first appeared in the Early Miocene of Africa by the presence of *Zaraffa* and *Prolybitherium* (Churcher, 1978; Geraads, 1996). In the past, this family was widespread both in Africa and Eurasia with a number of genera. Bohlin (1926) refered that family Giraffidae originated from Holarctic region. In the Early Miocene, giraffid appeared in south Asia, from where they migrated to South East Asia (Khan and Farooq, 2006). Nevertheless, the giraffid history is not clear in the Siwaliks (Gentry, 1999). Giraffids or their likely ancestors had been present in the Early Miocene from Bugti in Pakistan (Barry *et al*., 2005). The Family Giraffidae consists of almost thirty species throughout the Neogene of Old World (Bohlin, 1926; Hamilton, 1978; Geraads, 1986a, b; Janis and Scott, 1987; Gentry and Hooker, 1988).

Family Giraffidae evolved during Kamlial times in the Siwaliks, the specimen present in this Formation are relatively longer and slender than those of the modern giraffe (Solounias, 2007). Like many other mammalian groups, this family is also well represented in the Siwaliks of Pakistan **(**Table 2.1). The known giraffid material comprises of isolated incisors, canines, maxillae palatal fragments, mandibular rami and portions of axial skeleton. Fourteen giraffid species have been reported form the Siwaliks of Pakistan (Khan and Farooq, 2006). The Siwalik giraffid history goes back to the 19th century when Cautley in 1838 discovered an elongated third cervical vertebra of large size giraffid. Later many specimens were identified by Falconer and Cautley (1843), Pilgrim (1911), Matthew (1929), Colbert (1933, 1935), Sarwar and Akhtar (1987), Khan *et al*. (2005, 2010), and Bhatti *et al*. (2012a).

The first comprehensive study on “The Fossil Giraffidae of India” was made by Pilgrim (1911). He observed great diversity in the Siwalik giraffids. His work was later on reviewed by different workers such as Matthew (1929), Colbert (1935), Sarwar and Akhtar (1987), Sarwar (1990), Barry *et al*. (2005), Bhatti (2005), Bhatti *et al.* (2007a, 2012b). The Siwalik giraffid can be categorized in two groups: small size giraffids and large size giraffids. These species can be differentiated on the basis of dental morphology and skull patterns. The small forms comprise the genera *Progiraffa, Giraffokeryx* and *Giraffa* and the large forms include *Bramatherium, Indratherium, Sivatherium, Hydaspitherium, Helladotherium* and *Vishnutherium*. Many of the forms are being synonymised now. In the Lower Siwaliks of Pakistan, three extinct genera of family Giraffidae are found i.e. *Progiraffa, Giraffokeryx* and *Giraffa.*

The name *Progiraffa* was assigned by Pilgrim (1908). In the Potwar Plateau, *Progiraffa exigua* remained up to 16 million years. *Progiraffa* can be placed in the family Giraffidae due to presence of ossicones. However it can be differentiated from genus *Giraffokeryx* by the presence of well separated metastylid and protometaenamel complex (Hamilton, 1978; Barry *et al*., 2005). Fossils of Early Miocene giraffid *Canthumeryx sirtensis* are reported from Libya (Hamilton, 1973), Kenya (Hamilton, 1978), Egypt (Miller, 1999) and Uganda (Bishop, 1962, 1967). *Georgimeryx georgalasi* are recovered from Middle Miocene localities of Greece (Paraskevaidis, 1940). Morales *et al.* (1987) identified Middle Miocene *Injanatherium arabicum* from Al Jadidah, Saudia Arabia.

Genus *Giraffokeryx* is recorded from Southern Asia, Africa and few Astaracian age localities of Europe (Gentry, 1990). *Giraffokeryx punjabiensis* was identified by Pilgrim (1911) from the Chinji Formation of Phadial, northern Pakistan. Pilgrim’s work was supplemented by Matthew (1929) and Colbert (1933). Colbert (1933) recovered a skull from the Middle Miocene of northern Punjab and referred it to *Giraffokeryx*, which is one of the most complete descriptions of *Giraffokeryx*. *Giraffokeryx punjabiensis* disappeared from the Nagri Formation about 10 Ma, for the rest of Miocene, large giraffes were present (Barry *et al*., 1982). A few specimens are reported from the base of the Nagri Formation, nearby the boundary of the Chinji and Nagri formations (Khan *et al*., 2012).

Giraffokeryx punjabiensis was present in Asia (Pilgrim, 1910, 1911; Colbert, 1935; Bhatti, 2005; Bhatti *et al.*, 2012a; Khan *et al.*, 2012) and *Giraffokeryx anatoliensis* was recovered from Turkey (Geraads and Aslan, 2003). Churcher (1970) diagnosed *Palaeotragus primaevus* from Kenya but Gentry (1994) pointed out that morphologically these specimens were similar to *Giraffokeryx.* So latter in 1999, he transferred them into family Giraffokerycinae. *Giraffokeryx punjabiensis* and *Giraffokeryx anatoliensis* had shorter anterior ossicones and neck than *Giraffokeryx primaevus*. *Giraffokeryx chinjiensis* was reported by Sarwar (1990) by presence of three different upper molars from Chinji type locality. These specimens were different in dental morphology from *Giraffokeryx punjabiensis.* Aguiree and Leakey (1974) identified *Giraffokeryx* from Late Miocene locality of Kenya but Gentry (1997) thought that these fossils belong to Giraffinae. Some remains of *Giraffokeryx* aff. *punjabiensis* were described by Gentry (1990) from Pasalar (Turkey).

Palaeotragus primaevus was closely related to *Giraffokeryx*, present in Africa in Middle Miocene, some remains are also known from Eurasia and Greco-Iranian province (Kostopoulos and Sarac, 2005). *Palaeotragus primaevus* has been reported from Ngorora, Kenya (Hamilton, 1978) but its identification is disputable (Harris *et al.,* 2010). *Palaeotragus lavocati* is recovered by Heintz (1976) from Middle Miocene locality of Beni Mellal Morocco. *P. robinsoni* is identified from Tunisia (Crusafont-Pairo, 1979). *Palaeotragus germaini* recognized from Late Miocene to Early Pliocene localities of Tunisia (Burollet, 1956; Coppens, 1971), Morocco (Geraads, 1996) Algeria (Arambourg, 1959; Singer and Bone, 1960; Thomas and Petter, 1986; Sudre and Hartenberger, 1992) and South Africa (Hendey, 1970; Harris, 1974, 1976a). Some fossils are recovered from Kenya (Churcher, 1979) were closed to Giraffa (Geraads, 1986a). *P. coelophrys* have been reported from Iran (Bosscha Erdbrink, 1977; Campbell *et al*., 1980), *P. quadricornis* and *P. rouenii* from Samos Island Greece, Bulgaria and Turkey (Geraads *et al*., 2005; Kostopoulos and Sarac, 2005; Kostopoulos, 2009a). A new genus *Afrikanokeryx* has been described by Harris *et al.* (2010) from the Late Miocene locality of Ngorora (Kenya).

Matthew (1929) described *Giraffa priscilla* from the Lower Siwaliks. However, the fossils of this species were limited. Pilgrim (1911) found upper left second and third molars of *Giraffa priscilla* but post-cranial skeleton is not known. Basu (2004) identified *Giraffa priscilla* from Lower Siwaliks of Ramnager (India). According to him, fossils of *Giraffa priscilla* are Middle Miocene in age (Basu, 2004). Pakistan Lower Siwaliks i.e. Chinji Formation represent the same fauna.

Giraffa punjabiensis was the oldest known Late Miocene giraffe and ancestor of late Asian giraffids (Harris, 1991; Bhatti *et al*., 2012b). Its features were similar to *Bohlinia* but being an advanced form closely related to modern giraffes (Harris, 1976b). It was extinct by the end of Pliocene. Different species of *Giraffa* have been reported from Ethiopia, Kenya and Tanzania (Geraads, 1987, 1988; Geraads *et al*., 2004a, b). *Giraffa sivalensis* was a descendent of *Giraffa punjabiensis* and had an Early Pleistocene age (Churcher, 1978). It was extinct form Upper Siwaliks of Pakistan by the Mid Pleistocene (Mitchell and Skinner, 2003). Another taxon of Upper Siwalik giraffid i.e. *Camelopardalis affinis* (Falconer and Cautley, 1843) was synonymous with *Giraffa sivalensis* by Colbert (1935).

Bohlinia attica has been diagnosed from Greco-Iranian and Bulgaria from Late Vallesion to Late Turolian (Geraads *et al*., 2005; Kostopoulos, 2009b; Fortelius, 2010). Likius *et al.* (2007) identified Bohlina from Late Miocene locality of Chad but further examination is needed for its identification (Harris *et al*., 2010). *Bohlinia* cf. *attica* has been recovered from Cessaniti, Italy (Marra *et al*., 2011). Few remains attributed to *Birger bohlinia* have been found from Teruel Basin in Spain (Alcala and Montoya, 1994).

Honanotherium recognized by Bohlin (1926) from China. Latter Matthew (1929) and Colbert (1935) concluded that *Honanotherium* was similar to *Giraffa. Okapia stillei* was discovered by Dietrich (1942). Some fossils are recovered from Eastern Africa (Leakey, 1965; Cooke and Coryndon, 1970) but Harris (1976b) suggested that these fossils were closer to *Giraffa.*

Samotherium boisssieri reported from Greece, Turkey (Kostopoulous, 2009a; Fortelius, 2010), Egypt (Stromer, 1907), Libya (Harris, 1982), Tunisia (Coppens, 1971) and Kenya (Bishop and Pickford, 1975; Leakey and Leakey, 1986; Pickford *et al*., 1987). *Samotherium major* was identified from Late Miocene deposits of Greece by Kostopoulos (2009a). Remains of *S.* cf. *major* have been found in Turkey (Kostopolos and Sarac, 2005). *Samotherium* cf. *boissieri* was also recovered from Italy (Marra *et al*., 2011).

In Africa, *Giraffa* first appeared in Early Pliocene (Geraads *et al*., 2013). Fossils of *Giraffa camelopardalis* were recovered from Ethiopia (Asfaw *et al*., 2002), Israel (Haas, 1966; Bar-Yosef and Tchernov, 1972; Geraads, 1986b), Northern Africa (Romer, 1928; Howe and Movius, 1947; Arambourg, 1952, 1979; Singer and Bone, 1960; Geraads, 1981), Central Africa (Brunet and M.P.F.T, 2000), Eastern Africa (Kent, 1942a, b; Vaufrey, 1947; Cooke, 1963) and Western Africa (Joleaud, 1936). *Giraffa jumae* identified from Turkey, Africa and Middle East (Leakey 1965, 1970; Harris *et al*., 1988; Bruent *et al*., 1998; Geraads, 1998; Suwa *et al*., 2003; Wynn *et al*., 2006). *Giraffa pygmaea* was smaller than *G. camelopardalis* and *G. stillei*. It has been recognized from Ethiopia, Kenya and Malawi (Taieb *et al*., 1976; Kalb *et al*., 1982; Harris, 1991; Schrenk *et al*., 1993; Bromage *et al*., 1995). *Giraffa stillei* was larger than *G. jumae* and *G. camelopardalis*. It is known from Ethiopia and Africa (Dietrich, 1942; Geraads, 1994; Ward *et al.,* 1999). Arambourg (1947) diagnosed that it was synonym for *G. gracillis.*

Family Sivatheriinae originated in Siwaliks from *Giraffokeryx* via *Bramatherium* (Solounias, 2007). *Bramatherium* was only present in Asia (Geraads and Gulec, 1999). *Bramatherium perimense* was present in the Middle Siwaliks whereas *Bramatherium geraadsi* was found from the Upper Siwaliks (Table 2.1). It is differentiated by the presence of L-shaped protocone (Sarwar and Akhtar, 1987). Ossicone and molar fragments of *Bramatherium* were recovered from Abu Dhabi (Gentry, 1999) and from Turkey (Geraads and Gulec, 1999).

Helladotherium was described by Lydekker (1891) from Middle Siwaliks (Table 2.1). This extinct genus is also known from Miocene localities of Europe, Africa and Asia (Bohlin, 1926; Roman and Solignac, 1934; Joleaud, 1937; Bosscha Erdbrink, 1977; Gentry *et al*., 1999; NOW Database, 2003; Geraads *et al*., 2005; Kostopoulos and Sarac, 2005; Kostopoulos, 2009a).

Hydaspitherium was described from the Dhok Pathan Formation of the Middle Siwaliks. It is recognized by four species i.e. *Hydaspitherium grande, Hydaspitherium magnum, Hydaspitherium birmanicum* and *Hydaspitherium megacephalum* (Table 2.1). *Hydaspitherium grande* was the largest species of *Hydaspitherium* (Lydekker, 1878). Pilgrim (1910) differentiated *Hydaspitherium magnum* and *Hydaspitherium birmanicum* on the basis of molar size. *Vishnutherium iravaticum* was described by Lydekker (1876) from Irrawaddy Beds of Burma. The fossils of this species are also present in Middle Siwaliks of Pakistan (Bhatti, 2005; Bhatti *et al*., 2012c).

Sivatherium is represented in the Upper Siwaliks of Pakistan by a Pleistocene giraffe species *Sivatherium gigenteum*. A new genus *Indratherium majorii* (Pilgrim, 1910) present in the Upper Siwaliks was assigned to *Sivatherium giganteum* (Bohlin, 1926; Matthew, 1929; Colbert, 1935). By the Late Miocene time, the subfamily Sivatheriinae was present in Africa (Guerin, 1966; Geraads, 1985, 1994). Sivatheres also recorded from Algeria (Romer, 1928; Singer and Bone, 1960; Arambourg, 1979; Sudre and Hartenberger, 1992), Chad (Brunet *et al*., 1998; Vignaud *et al*., 2002; Likius *et al*., 2007), Djibouti (Geraads, 1985), Ethiopia (Arambourg, 1947; Taieb *et al*., 1976; Kalb *et al*., 1982; Woldegabriel *et al*., 1994; Heinzelin *et al*., 1999; Geraeds *et al*., 2002; Suwa *et al*., 2003; Semaw *et al*., 2005), Kenya (Kent, 1942 a, b; Cooke, 1963; Leakey, 1965, 1970; Harris, 1976a , 1991, 2003), Malawi (Mawby, 1970; Schrenk *et al*., 1993; Bromage *et al*., 1995), Morocco (Geraads, 1996; Raynal *et al*., 1999), South Africa (Hendey, 1970, 1974, 1976, 1981), Sudan (Arambourg, 1960), Tanzania (Hopwood, 1934; Dietrich, 1942; Geraads, 1987; Gentry, 1997), Tunisia (Burollet, 1956; Coppens, 1971; Robinson and Black, 1974), Uganda (Geraads, 1994), United Arab Emirates (Gentry, 1999), Zaire (Boaz, 1990) and Zambia (Cooke, 1963).

Table 2.1: Vertical distribution of the Siwalik giraffids according to age of Siwalik formations.

Subgroups	**Age**	**Formations**	**Giraffids**
Upper Siwaliks	0.6 Ma	Boulder Conglomerates	Non-fossiliferous
	2.6 Ma	Pinjor	*Bramatherium geraadsi* *Sivatherium giganteum* *Giraffa sivalensis* *Indratherium majori* *Camelopardalis affinis*
	3.4 Ma	Tatrot	Giraffid remains absent
Middle Siwaliks	10.0 Ma	Dhok Pathan	*Vishnutherium iravaticum* *Bramatherium perimense* *Hydaspitherium megacephalum* *Hydaspitherium grande* *Hydaspitherium magnum* *Hydaspitherium birmanicum* *Helladotherium grande* *Giraffa punjabiensis*
	11.2 Ma	Nagri	Few dental fragments of Giraffokeryx and giraffids.
Lower Siwaliks	14.2 Ma	Chinji	*Giraffa priscilla* *Giraffokeryx chinjiensis* *Giraffokeryx punjabiensis*
	18.3 Ma	Kamlial	Unidentifiable giraffid remains.

2.2 Stratigraphy

The Siwaliks have an abundant of fossil record from 18 to 1 million years ago (Badgley *et al*., 2008). Ojha *et al.* (2009) determined the age of Siwalik formations from 15 to 1 Ma by using magnetic polarity and carbon isotope methods. Many scientists (Bhattacharya and Mirsa, 1963; Bhattacharya, 1970; Chaudhri and Gill, 1983, Bagati and Kumar, 1994; Biswas, 1994; Raiverman and Suresh, 1997; Raiverman, 2002) have worked on clay mineralogy of the Middle Siwalik sediments. According to Bagati and Kumar (1994), Raiverman and Suresh (1997), Kumar *et al.* (1999), Raiverman (2002) and Ghosh *et al.* (2003), the late Neogene sediments of the Siwaliks consist of abundant illite and smectite. The thickness of the Siwaliks vary widely from place to place, however it is estimated from 4865 m thick (Colbert, 1935) to 6080 m thick (Wadia, 1975).

Falconer (1868) was the first to investigate the Siwalik Biostratigraphy. He recognized that Siwaliks represented a single continuous series of continental deposits (Table 2.2). Lydekker (1883b) divided the Siwaliks into two horizons i.e. Upper and Lower and assigned Pliocene age to it (Table 2.2).

Pilgrim (1910, 1913, 1934), as a result of many years of work in the Subcontinent, divided the Siwaliks into Lower, Middle and Upper Siwalik recognizing two faunal zones (Kamlial and Chinji) in the Lower Siwaliks, two (Nagri and Dhok Pathan) in the Middle Siwaliks and three (Tatrot, Pinjor and Boulder Conglomerates) in the Upper Siwaliks (Table 2.2). He correlated the Siwaliks with mammal horizons of Europe and believed that these fluviatile deposits range from Middle Miocene to Lower Pleistocene. Pilgrim's work was reviewed by Matthew (1929), who placed the Siwaliks somewhat higher in the geological time scale. He also believed that the Siwalik sedimentation was not a continual process and there was a faunal break first at Lower/Middle and then at Middle/Upper Siwalik transition. Colbert (1935) disagreed with Matthew's opinion, he suggested that the Siwalik Sedimentation was a continual process and there was no break during deposition.

Different workers assigned different ages to the Siwalik formations (Acharyya, 1994). In Pilgrim's opinion (1910), Kamlial, Chinji and Nagri are Miocene in age where as Dhok Pathan, Tatrot, Pinjor and Boulder Conglomerate zones are Pliocene in age. According to Colbert (1935), Kamlial is Upper Miocene and all others are Pliocene in age (Table 2.2). Jacobs (1978) correlated Chinji with Astaracian, Nagri with Valesian and Dhok Pathan with Turolian of Europe.

According to him, Chinji, Nagri and Dhok Pathan are Miocene in age. Thomas (1984) investigated that the Chinji is Middle Miocene, the Nagri and Dhok Pathan are Upper Miocene and the Tatrot is Pliocene in age.

Table 2.2: Historical Review of the Stratigraphic Sections of Siwaliks.

	Palaeontologists	**Subgroups**	**Faunal Zones**	**Age**
Siwalik Series	Colbert (1935)	Upper Siwaliks	Boulder Conglomerate Pinjor Tatrot	Pleistocene Pleistocene Upper Pliocene
		Middle Siwaliks	Dhok Pathan Nagri	Pliocene
		Lower Siwaliks	Chinji Kamlial	Pliocene Upper Miocene
	Matthew (1929)	Upper Siwaliks Middle Siwaliks Lower Siwaliks		Lower Pleistocene Middle Pliocene Lower Pliocene
	Pilgrim (1910, 1913, 1934)	Upper Siwaliks	Boulder Conglomerate Pinjor Tatrot	Lower Pleistocene Upper Pliocene
		Middle Siwaliks	Dhok Pathan Nagri	Lower Pliocene
		Lower Siwaliks	Chinji Kamlial	Middle Miocene
	Lydekker (1883b)	Upper Horizon Lower Horizon		Pliocene
	Falconer (1868)	A Unit Fauna		Miocene

Bajwa and Akhtar (1986) have worked out the rate of deposition of Siwalik sediments in Potwar Basin. According to them, the rate was minimum i.e. 0.04 mm/yr in Kamlial and maximum (0.20 – 0.25 mm/yr) in Nagri times. The Siwalik sequence completed at a rate of 0.1-0.4 mm/yr (Johnson *et al*., 1985; Harrison *et al*., 1993). Miocene mammalian record shows similarities between south Asia and Africa where as Pliocene fauna is closely similar to Northern and Western Eurasia (Barry and Flynn, 1989). According to Chauhan (2003), the Siwaliks are divided into Upper, Middle and Lower Siwaliks on the basis of lithofacies variation and faunal assemblages.

According to Stratigraphic Committee of Pakistan (1974), the Sub-Himalayan molasses succession has been divided into two groups, i.e. Rawalpindi Group and Siwalik Group (Table 1.3). The Rawalpindi Group is ranging from Early Miocene comprises Muree and the Kamlial Formation (Fatmi, 1973; Meissner *et al*., 1974). The Siwalik Group ranging from Middle Miocene to Early Pleistocene, comprises Chinji, Nagri, Dhok Pathan and Soan formation, thus excluding the Kamlial formation from the Siwaliks and combining the Tatrot and Pinjor zones of Pilgrim (1913) into a single Formation i.e. Soan formation. Cheema *et al*. (1977) divided the Siwaliks into Kamlial, Chinji, Nagri, Dhok Pathan, Samwal and Tatrot.

Table 2.3: A stratigraphic position of the Neogene freshwater strata of Pakistan (according to Stratigraphic Committee of Pakistan, 1974).

Groups	Subgroups	Formations	Age
Siwalik Group	Upper Siwaliks	Soan	Early Pleistocene ↑
	Middle Siwaliks	Dhok Pathan Nagri	Pliocene ↑ Late Miocene
	Lower Siwaliks	Chinji	Middle Miocene
Rawalpindi Group		Kamlial Murree	Early Miocene

2.2.1 Siwaliks

Siwaliks have been derived from the rising Himalayan rocks to the north and northwest. The Siwalik rocks consist of sandstones, siltstones, mudstones and clays. The Lower, Middle and Upper Siwaliks are distinguished on the basis of texture (Quade *et al*., 1995), minerals, bedding characteristics (Parkash *et al*., 1980) and palaeontological records (Najman *et al.*, 2004; Najman, 2006). The Siwalik formations can be differentiated by percentage of sand. In Chinji formation, sand is lower than 50%. In Nagri formation, it is higher than 50% (Fatmi, 1973; Pilbeam *et al*., 1979). The sediments accumulation rate was double in the Middle Siwaliks as compared to the Lower Siwaliks (Meigs *et al.*, 1995; Burbank *et al*., 1996).

Lower Siwaliks

The Lower Siwaliks is 1200 meter thick. It consists of Kamlial and Chinji formations.

Kamlial Formation

This formation is widely distributed in Kohat and Potwar plateau. It is 90 meter thick around Kamlial Village and 120 meter thick at Kohat. Pinfold (1918) proposed the name "Kamlial Stage" due to presence of rocks near Kamlial village (Attock district). The term Kamlial formation was described by Lewis (1937), which was formalized by the Stratigraphic Committee of Pakistan (1974).

This Formation consists of sandstones, sandy mudstones and conglomerates. The sandstones are brown to greenish grey, fine to medium grained and cross-bedded. Sand particles of this formation are subrounded and sandstones are matrix. Presence of multistoried sandstones deposition is due to Indus River which had been diverted from its current position during Kamlial formation (Stix, 1982; Hutt, 1996; Johnson *et al.*, 1985; Najman *et al*., 2003). The mudstones are of dark red to maroon and purple colours (Kafayat Ullah *et al*., 2006). Work on this formation was done by detrital zircon fission track study (Cerveny *et al*., 1988), petrographic and facies study (Abbasi and Friend, 1989; Hutt 1996; Pivnik and Wells, 1996) which shows that mudstone and siltstone facies in this formation are in low proportion.

This Formation has been divided into major channel type sand bodies and flood plain type tubular sand bodies. The major channel type sand bodies are comprised of medium grained grey sandstones which are multistoried, 4-6 m thick having trough cross-bedding (Abbasi, 1998). The flood plain type tubular sand bodies were deposited by a mixed load river activity (Abbasi, 1991). Minerals such as tourmaline, chlorite, greenish biotite and glauconite are present in Kamlial sandstones (Abbasi and Friend, 1989; Abbasi and Khan, 1990). Heavy minerals epidote, garnet, monazite apatite, chromite and fluorite are present in Kamlial rocks (Kafayat Ullah, 2009).

The Kamlial formation approximately ranged from 18.3 to 14.2 million years (Barry *et al*., 2002). The chief faunal elements are *Deinotherium pentapotamiae Gomphotherium angustidens, palaeocherus pascoci, Bunolistridon, Listriodon* and *Conohyus sindiense* and some remains of family Giraffidae (Barry and Flynn, 1989). On the basis of magnetic stratigraphic studies, the age of the Kamlial formation is from 18.3 to 14.2 Ma (Johnson *et al*., 1982a, b). In the Pakistan Siwaliks, the giraffid first appeared in Kamlial formation (Raza *et al*., 1984). Same kinds of rocks are present in lower Indus Basin known as Manchar Formation.

Chinji Formation

The Chinji formation is about 2300 feet in thickness. The name ‘Chinji zone’ was proposed for the upper faunal sub-division of the Lower Siwaliks by Pilgrim in 1910. Pascoe (1964) described it as Chinji Stage but Lewis (1937) upgraded it as Chinji Formation after the village Chinji-Kotehra. This has been adopted by the Stratigraphic Committee of Pakistan (1974). The type section is located south of the Chinji village (Lat. 32^o 41’ N; Long 72^o 22’E) in the Chakwal district, the Punjab province, Pakistan. This Formation is 1900 m thick in Shinghar range, which is 11.8 Ma and 8 Ma old (Khan and Opdyke, 1993), 750 m thick south of the Chinji village in Chakwal district (type locality) and 500 m thick in Dhok Bun Amir Khatoon area.

In this formation cross-bedded facies, sandstone facies, inter-bedded mudstone facies, siltstone and cross-laminated facies have been identified (Kafayat Ullah, 2009). It consists of bright red clays and sub-ordinate ash grey sandstones (Willis and Behrensmeyer, 1994). The clays are red, ash grey to brown, fine to medium grained with scattered pebbles of quartz (Khan *et al*., 2009). In the type section, ratio of siltstone to sandstone is 4:1. Red, green, grey, brown silt and clay mudstones have been recognized. Calcareous nodules are also present which vary in size (Behrensmeyer and Tauxe, 1982; Badgley, 1986).

This deposition is result of mix load rivers (Collinson, 1996). These rivers transport fine grained sandy and gravel sediments (Bluck, 1971). Multistoried sandstones bodies in Chinji village are about 80-200 m in width and 4-13 meter deep. Chinji Palaeosols are 1-3 meter thick. This Formation is Middle Miocene in age

(Barry *et al*., 2002). Epidote, monazite, apatite, garnet, rutile are minerals present in this formation (Kafayat Ullah *et al*., 2006). Chinji formation has decrease sandstones thickness, small palaeochannels, less sediment accumulation rate and palaeo discharge as compared to Nagri (Willis, 1993a; Zaleha, 1997a, b). However drainage network increased from Chinji to Nagri Formation (Willis, 1993b, Khan *et al*., 1997; Kumar *et al*., 2003).

It is characterized by the presence of *Dryopithecus, Sivacanthion, Dissopsalis, Vishnucyon, Sivaelurus, Gomphotherium, Gaindatherium, Bunolistriodon, Listriodon Tetraconodon, Hyotherium, Microstonyx, Hemimeryx, Dorcabune, Sanitherium, Giraffa* and *Giraffokeryx* (Pilgrim, 1911, 1913; Matthew, 1929; Colbert, 1935; Khan *et al.*, 2008, 2009, 2010; Khan and Akhtar, 2011). Three giraffid genera *Progiraffa, Giraffa* and *Giraffokeryx* have been recorded from the Chinji Formation.

Middle Siwaliks

The Middle Siwaliks is 1800 meter thick. It comprises Nagri and Dhok Pathan formations. Conglomerate facies and medium to coarse grained, grey mica rich sandstones are present in this Formation (Cotter, 1933).

Nagri Formation

Pilgrim (1913) introduced it "Nagri zone" or "Nagri Stage". But later on the Stratigraphic Committee of Pakistan (1974) suggested it as Nagri Formation. In this Formation, cross-bedded channel, sandstone facies, siltstone facies, channel conglomerate facies and mudstone facies are diagnosed (Kafayat Ullah, 2009). Mudstone and siltstone facies are in low proportion. The Nagri Formation was deposited by rivers which are dominated by sand and gravel. Brown coloured palaeosols with calcareous nodules suggest humid climate for deposition of these sediments (Kumar *et al.*, 2004).

It consists of sandstones with sub-ordinate clays and conglomerates. The sub-ordinate clays are sandy, chocolate brown, reddish grey or pale orange. The sandstones are greenish grey, medium to coarse grained, cross-bedded and massive. Conglomerates are pebbles of igneous rocks and Eocene limestone. The thickness of Nagri formation is about 500-900 meters. Near the type locality, the base was dated by fission-track dating of volcanic ash at about 10.8 Ma (Johnson *et al*., 1985).

The Nagri formation is moderately fossiliferous. It is characterized by the presence of *Indraloris, Dryopithecus cautleyi, Ramapithecus, Crocuta gigantea, Orycteropus, Microstonyx, Lophochoerus, Conohyus, Propotamocherus, Hippohyus* *deterrai, Hippopotamodon* and *Hipparion.* In Nagri Formation, some giraffid dental fragments of *Giraffokeryx punjabiensis and Giraffa priscilla* are present.

Dhok Pathan Formation

The Dhok Pathan Formation is well exposed in the Chakwal district of the Punjab province (Pakistan) and it is Late Miocene in age (Barry *et al*., 2002; Khan *et al*., 2008). Pilgrim (1913) named it as “Dhok Pathan” zone. Later on, Lewis in 1937 called it “Dhok Pathan” Formation and this name was accepted by the Stratigraphic Committee of Pakistan (1974). According to Stratigraphic Committee of Pakistan this Formation has two principal reference sections i.e. Gaud River section (Mianwali district, Pakistan) and Spintangi section (Quetta region, Pakistan).

This Formation has monotonous cyclic alternation of sandstones and clays. Sandstones are white, light grey, greenish grey, brownish grey, occasionally grey, reddish brown, brown or buff, thick bedded, calcareous moderately cemented, soft, cross bedded. The clays are orange brown, dull red or reddish brown, occasionally rusty orange, greenish yellow, yellowish grey or chocolate. Minor intercalations of yellowish brown siltstones are present.

It is abundantly fossiliferous and is characterized by the following faunal elements. *Cercopithecus hasnoti*, *Ictitherium*, *Deinotherium indicum, Tetralophodon punjabiensis*, *Synconolophus dhokpathanensis*, *Anancus perimensis*, *Stegolophodon latidens*, *Stegodon bombifrons*, *Stegotetrabelodon, Hipparion, Cormohipparion, Lophochoerus, Tetraconodon, Sivachoerus, Propotamochoerus, Sus, Hippohyus, Hippopotamodon, Tragocerus, Proleptobos.*

Five genera and eight species of the giraffid are present in the Dhok Pathan Formation (Sarwar and Akhtar, 1987). These are *Vishnutherium iravaticum*, *Bramatherium perimense, Hydaspitherium megacephalum, H. grande, H. magnum, H. birmanicum, Helladotherium grande* and *Giraffa punjabiensis.* According to Johnson *et al*. (1985), near the type locality, the base was dated by fission track dating at about 8.5 Ma. The thickness of this Formation is 500-825 m.

Upper Siwaliks

Upper Siwaliks is 1800 meter thick. It is divided into Tatrot, Pinjor and Boulder Conglomerate Zones. Clast Conglomerates are present in this subgroup (Burbank and Beck, 1989).

Tatrot Formation

It is mainly composed of hard brown sandstones. The Formation is scantily fossiliferous and the notable elements are *Elephas, Sivachoerus, Tetraconodon, Potamochoerus, Sus, Hippohyus, Sivahyus,* and *Hexaprotodon.* Giraffes are absent in the Tatrot Formation.

Pinjor Formation

It comprises sands and variegated clays. It is richly fossiliferous with typical development of the Upper Siwalik fauna. The chief faunal elements are the following: *Semnopithecus, Nesokia, Caprolagus, Sivacyon, Crocuta sivalensis, Stegodon insignis, S. pinjorensis, Elephas hysudricus, Equus sivalensis, Coelodonta, Rhinoceros sivalensis, Hippohyus, Camelus sivalensis, Cervus punjabiensis, Sivatherium, Leptobos, Hemibos and Bison sivalensis.* Pinjor comprises five genera and five species of giraffids. These are *Bramatherium geraadsi, Sivatherium giganteum, Giraffa sivalensis, Indratherium majori* and *Camelopardalis affins.*

Boulder Conglomerate Formation

The Zone is chiefly recognized by its large heavy boulders indurated by infiltrations of siliceous material. The zone is almost non-fossiliferous.

Soan Formation

Kravtchenko (1964) proposed the name Soan Formation, which has been accepted by Stratigraphic Committee of Pakistan. The Tatrot and Pinjor and Boulder Conglomerate of the Upper Siwaliks are collectively known as Soan Formation (Shah, 1980). The conglomerates with subordinate inter-beds of sandstones, siltstones, compact massive variety of pebbles and boulders of different sizes. Claystones may be orange, brown, pink, red and pale. Sandstones may be grey, greenish and course grained (Badgley and Behrensmeyer, 1980; Badgley, 1986).

According to Khan (1987), the Soan Formation is Lower Pleistocene in age. The exposed thickness is 200-300 m. The base locally rests on an unconformity dated by fission-track dating of a volcanic ash at 1.9 $\pm$ 0.4 Ma (Raynolds, 1980).

Chapter 3

MATERIALS AND METHODS

3.1 Materials

A number of field trips were arranged to explore the fossils of the giraffids from the Lower Siwaliks of northern Pakistan. The localities such as Jaba, Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon, Dhulian, Ghungrilla, Dial, Chabbar Sayadan, Lava, Phadial, Bhelomar Parrhewala and Ratial were explored and many fossils were discovered. In order to collect the fossils of the ancestral forms, special attention was paid to the areas bearing outcrops of the Kamlial and Lower Chinji formations. As a result, fossils of *Progiraffa exigua* were procured. The material comprises maxillary and mandibular fragments, and isolated teeth. The embeded sedimentary matrix was carefully removed with the help of the chisels, pin headed hammers, various types of needles and brushes.

The material was carefully washed, cleaned in the palaeontology laboratory of Zoology Department of GC University, Lahore. Broken parts were carefully assembled by using various types of gums. The tightly encrusting sediments were removed by using hydrochloric acid, phosphoric acid and acetic acid. A hand lens was used for morphological analysis and taxonomy. Each specimen shows collection year and the serial number of the respective year (e.g. GCUPC 1141/09, the nominator denotes the serial number of the collection and the denominator indicates the collection year; GCUPC is an institional abbreviation). Some specimens present in Punjab University Palaeontological Collection in Zoology Department, University of the Punjab, Lahore, Pakistan (PUPC) are included in this study. The capital letter with superscript indicates upper dentition and subscript for lower dentition (e.g. M^1 represents upper first molar and M_1 for lower first molar).

3.2 Measurements

The measurements were taken by a digital vernier caliper and expressed in millimeters. The length and width of the teeth were measured at occlusal level, height were measured on the protoconids of lower premolars and metastylids of lower molars.

3.3 Comparison

This material is compared with the specimens present in the American Museum of Natural History New York (AMNH), Indian Museum, Calcutta (GSI), Punjab University Palaeontological Collection Stored in Zoology Department, University of the Punjab, Lahore, Pakistan (PUPC), Geological Survey of Pakistan-Sind Collection, Quetta, Pakistan (GSP-S), Geological Survey of Pakistan-Harvard University Project, USA (GSP-Y) and Geological Survey of Pakistan-Howard University Project, USA (GSP-H).

3.4 Depository

The studied material is housed in the Palaeontology Laboratory of the Zoology Department, GC University, Lahore and the Palaeontology Laboratory of the Zoology Department, University the Punjab, Lahore, Pakistan.

3.5 Photography

The well preserved specimens are selected for the photography and presented in the Systematic chapter.

3.6 Systematics and terminology

The systematics follows Solounias (2007) and the terminology follows Hamilton (1973), Gentry (1994), Gentry *et al.* (1999) and Khan *et al*. (2009).

3.7 Tooth morphology

The dental formula of family Giraffidae is 0/3, 0/1, 3/3, 3/3 = 32. Giraffid premolars show a gradual complexity, second premolar being the simplest and fourth premolar being the most complex and are having much similarity with the molars. Teeth of the molar series resemble each other. All the three teeth are constructed on the same general plane. However in M_3, hypoconulid is attached posteriorly.

Upper premolars have distinct labial cusps but lingual cusps are mostly fused at their apices (Figures 3.1, 3.2). The upper dentition consists of two high labial cusps (Para- and metacones). Protocone and metaconule are lingual cusps. Mesostyle is present between para- and metastyles labially. The entostyle is present between lingual cusps. Anterior and posterior fossettes are present between anterior and posterior cusps (Figure 3.3).

In lower premolars, the posterior part of the tooth is generally broader than the anterior ones. In P_2 and $P_{3,}$ proto- and hypoconids are labial cuspids. Para-, meta- and entoconids are lingual cuspids. Para- and entostylids are present anterolingually and posteroingually (Figure 3.4). The fourth premolar is different from P_2 and P_3 in general contour as well as in arrangement and position of the cuspids. P_4 and all lower molars have proto- and hypoconids labially and meta- and entoconids lingually (Figures 3.5-3.7). The metastylid is present between meso- and entostylid (Figures 3.6, 3.7). The ectostylid is found between labial cuspids. In M_3, hypoconulid is present posteriorly (Figure 3.7).

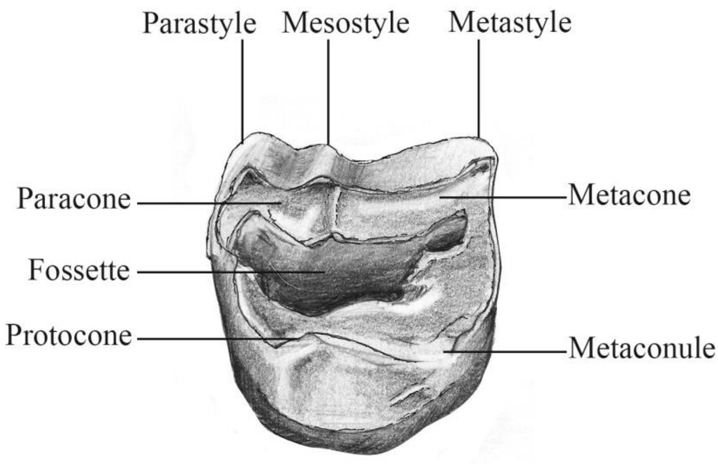


Figure 3.1: Topography of giraffid upper third premolar (anterior to left, labial up).

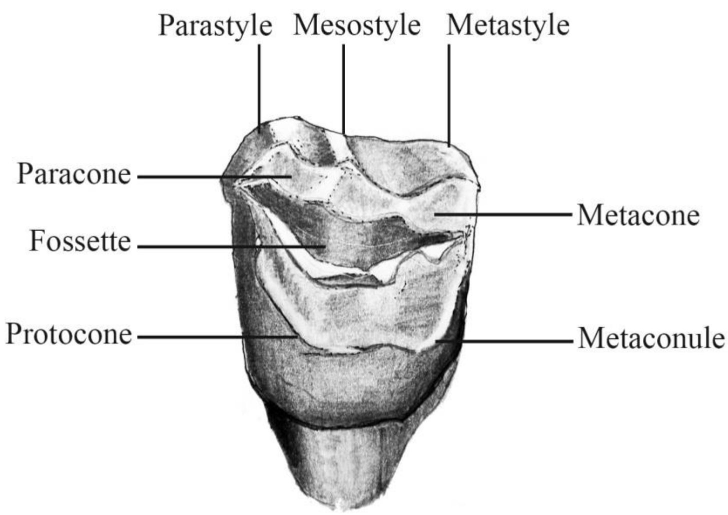


Figure 3.2: Topography of giraffid upper fourth premolar (anterior to left, labial up).

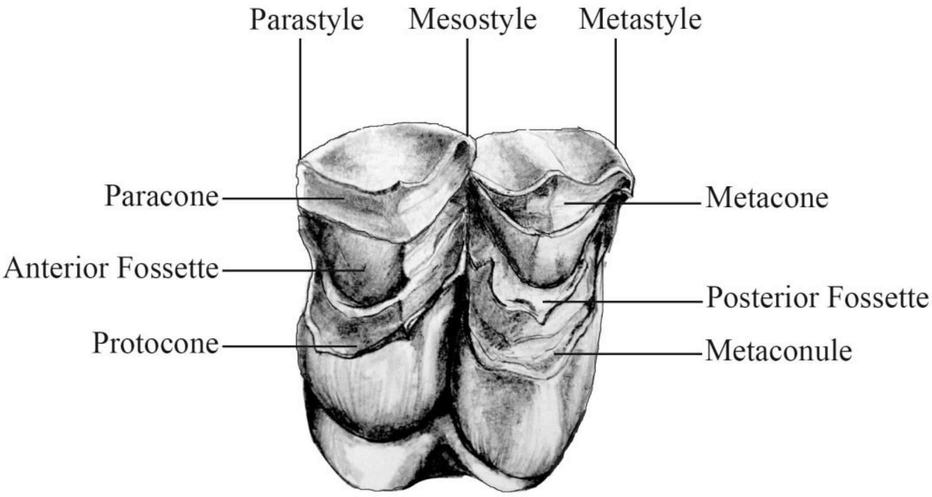


Figure 3.3: Topography of giraffid upper molar (anterior to left, labial up).

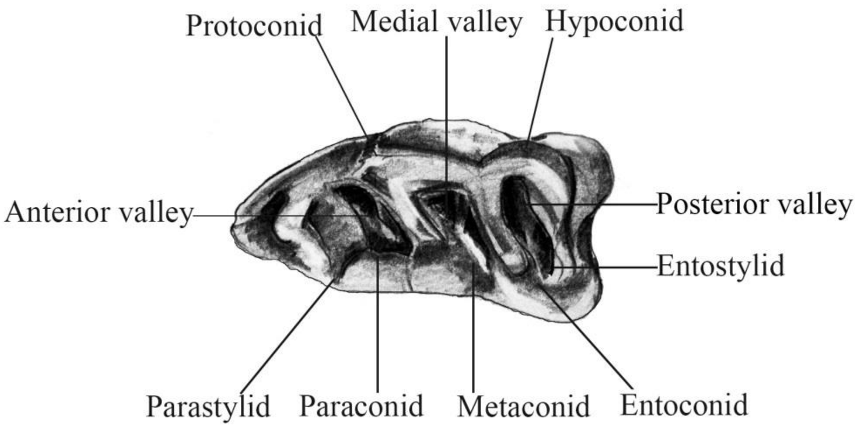


Figure 3.4: Topography of giraffid lower third premolar (anterior to left, labial up).

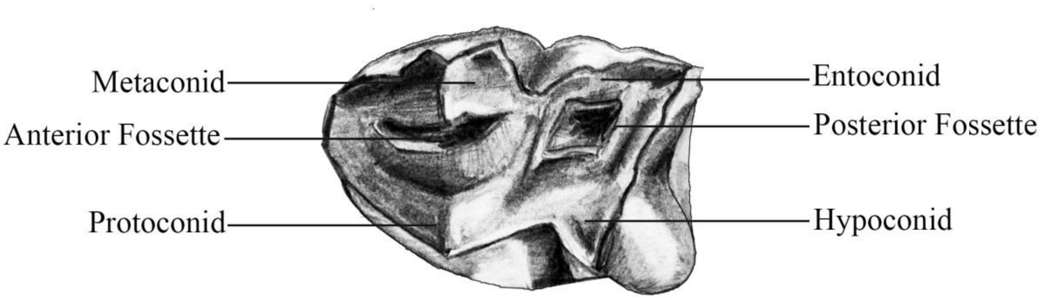


Figure 3.5: Topography of lower fourth premolar (anterior to left, labial down).

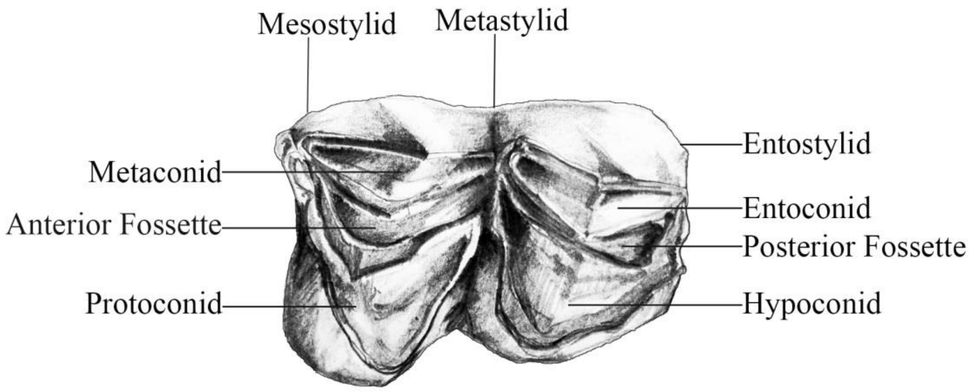


Figure 3.6: Topography of giraffid lower second molar (anterior to left, labial down).

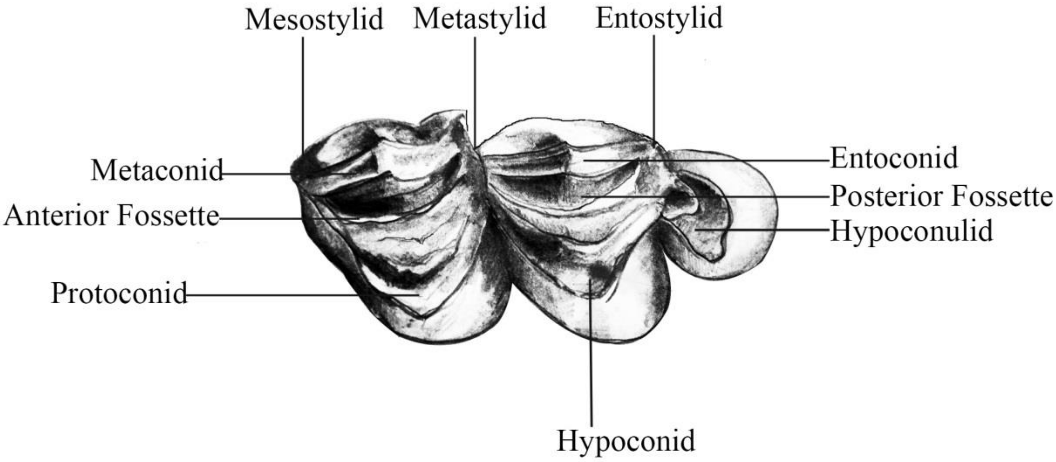


Figure 3.7: Topography of giraffid lower third molar (anterior to left, labial down).

Chapter 4

RESULTS

4.1 SYSTEMATIC PALAEONTOLOGY

Order ARTIODACTYLA Owen, 1848

Suborder RUMINANTIA Scopoli, 1777

Infraorder PECORA Linnaeus, 1758

Superfamily GIRAFFOIDEA Gray, 1821

Family GIRAFFIDAE Gray, 1821

Subfamily PROGIRAFFINAE Pilgrim, 1911

4.1.1 Genus *PROGIRAFFA* Pilgrim, 1908

Type species

Progiraffa exigua Pilgrim, 1908

Generic diagnosis

Members of this genus are of moderate sized. Ossicones present, dentition brachyodont with rugose sculpture of enamel. Palaeomeryx fold is not present. Postmetaconule crista is bifurcated. Anterior inner cingulum is prominent. Metastylid is large but separated from metaconid (Pilgrim, 1911; Barry *et al*., 2005).

Geographic distribution

Progiraffa is recorded from Pakistan and India (Pilgrim, 1908, 1911; Barry *et al*., 2005).

Included species

Progiraffa exigua Pilgrim, 1908; *Progiraffa sivalensis* Pilgrim, 1911

Progiraffa exigua Pilgrim, 1908

Lectotype

GSI B491, a left second molar.

Type locality

Bugti Hills, Baluchistan, Pakistan (Pilgrim, 1908).

Stratigraphic range

Bugti Hills, Zinda Pir, Manchar sites (Pilgrim, 1910, 1911; Barry *et al*., 2005).

Specific diagnosis

Teeth are brachyodont with rugose enamel. Upper molars with distinct bifurcation of postmetaconule crista. Postprotocrista and premetaconule crista linked with enamel complex. A well developed cingulum is present anteriorly. *Palaeomeryx* fold is absent.

Localities and age

The material is collected form the Lower Siwalik localities i.e. Jaba, Chinji Rest House, Rakh Wasnal, Dhok Bun Amir Khatoon and Ghungrila with estimated age of 18.3 -13.2 Ma (Barry *et al*., 2002; Nanda, 2002, 2008).

New material (in parenthesis the inventory number and the locality name are given):

Upper dentition: A left maxillary ramus with DP^{2-4}-M^1 (GCUPC 1149/12, Dhok Bun Amir Khatoon), rDP^3 (GCUPC 984/09, Jaba), lP^2 (GCUPC 1145/12, Dhok Bun Amir Khatoon), lM^{1s} (PUPC 12/55, PUPC 88/10, Chinji Rest House), rM^{1s} (GCUPC 1137/09, Jaba; PUPC 84/77, Rakh Wasnal), rM^{2s} (GCUPC 1136/09, Jaba; GCUPC 1177/09, Rakh Wasnal; GCUPC 1180/09, Dhok Bun Amir Khatoon; GCUPC 230/99, Chinji Rest House)

Lower dentition: rP_2 (PUPC 81/91, Ghungrila), lP_3 (PUPC 71/70, Rakh Wasnal), rM_{2-3} (PUPC 66/07, Ghungrila).

Description

Upper dentition

GCUPC 1149/12 is a left maxillary ramus having three deciduous molars and one permanent molar. The molars are well preserved and broad crowned (Figure 4.1).

DP^{2-3}

These are nicely preserved and half worn [Figures 4.1, 4.2 (2)]. A thick layer of cingulum is present anteriorly. The enamel layer is thick, shiny, smooth and corrugated. All the four principal cusps are quite conspicuous having unequal configuration. The protocone and metaconule are lingual cusps, low in vertical height than labial cusps i.e. paracone and metacone. The protocone is L-shaped. The cingulum is well marked at the base of protocone. The preprotocrista is wavy and contiguous with preparacrista. The enamel layer is thick, shiny and corrugated. The postprotocrista is adjoining with premetaconule crista.

The metaconule is present posterior to protocone. It is V-shaped structure having thick enamel layer. The postmetaconule crista is somewhat longer and extensively worn than premetaconule crista, so dentine is clearly visible on this cusp.

The paracone is slightly worn and dentine is exposed. Postparacrista is shorter than preparacrista. The preparacrista is wavy and forms a pillar like parastyle which is thick proximally but has a distinct bifurcation distally. The anterior median rib is very prominent and thick. The parastyle is supported by a thick multituberculated cingulum and cingular ridges.

The metacone is inverted V-shape structure present posterior to paracone. The metacone is supported by metastyle which is formed by extension of postmetacrista forwardly and folded backwardly. The thick enamel lining of prematacrista extends anteriorly and postparacrista posteriorly and outwardly to form a very strong and thick mesostyle. It is thick proximally and narrows distally. The metaconid bear a prominent median rib. The metasyle and mesostyle are attached at the base of the crown. The anterior fossette between protocone and paracone is crescent in shape, while posterior fossette between metaconule and metacone is V-shaped and shallow. Longitudinal valleys are wavy and deep while transverse valleys are rectilinear and open labially.

DP^4

The DP^4 (GCUPC 1149/12) is well preserved and square in outline (Figure 4.1). A thick cingulm layer is present on all sides of crown but it is more prominent lingually. The enamel is thick, shiny and wrinkled. The tooth is moderately worn lingually and it is slightly worn labially. The postprotocrista is low in vertical height than preprotocrista. The protocone is supported by a cingular ridges and cingulum. The metaconule is present posterior to protocone. The premetaconule crista is shorter in length than postmetaconule crista. There is distinct bifurcation in postmetaconule crista.

The paracone is inverted V-shaped structure. It is posteriorly contiguous with premetaconule crista through a narrow channel. Preparacrista and postparacrista are almost equall in size. Preparacrista extends forward and folded backward anteriorly to produce a strong parastyle. Metacone is similar in shape to protocone. It is just touch by wear so its enamel border is thick and corrugated. The enamel lining of postmetacrista posteriorly folded back to form thick metastyle. The enamel folding of premetacrista extends anteriorly and postparacrista posteriorly and outwardly to form a very strong and thick mesostyle. It is thick and broad proximally and narrows distally. The meso- and metastyles unite at the crown base. The meta- and paracones bear a conspicuous median ribs.

The anterior fossette present between protocone and paracone is deep. Posterior fossette present between metaconule and metacone is shallow. The longitudinal valley is wavy and deep while transvers valley straight, shallow and wide open lingually and labially.

P^2

A thick layer of cingulum is present antero-lingually and fairly developed all around the crown [Figure 4.2(1)]. All the principal cusps are present. The protocone is half-moon in shape, extensively worn forming a very large dentinal island. Its anterior crest is shorter than posterior crest. The cingulum is well developed around it. The postero-lingual metaconule is somewhat U shaped. Due to extensive wearing, the metaconule and protocone are closely oppressed to each other, therefore it is difficult to identify the demarcation between these two cusps. It forms a continuous sagittal valley thus its dental morphology is obscured. The paracone is almost worn, only the enamel layer at the labial boarder is visible. This enamel layer slope anteriorly and backwardly to form a strong, thick but low in vertical height pillar like parastyle which is broad at the base of the crown.

The metacone is elongated in shape. It is contiguous with postmetaconule crista by a narrow channel. The enamel of postmetacrista folded back posteriorly to form a prominent metastyle. The mesostyle is shiny and highly corrugated. It is higher than para- and metastyles. A very large and deep fossette is present between lingual and labial cusps. It is oval in shape. The transverse valley is open lingually and labially. The longitudinal valley is wavy and shallow anteroposteriorly.

M^1

The first molars are excellently preserved and in middle stage of wear [Figures 4.1, 4.2 (3-5)]. In general contour, these are almost square in outline. A thick layer of cingulum is present anteriorly, lingually and labially, it is quite thin posteriorly. The enamel is shiny, corrugated and almost uniform in thickness. All the four cusps i.e. protocone, metaconule, paracone and metacone are well differentiated.

The protocone is moderately worn and dentine is clearly visible forming V-shape dentinal islets. The preprotocrista is elongated than postprotocrista. Cingulum is thicker and prominent at anterior side of preprotocrista. The protocone is supported by cingular ridges and is contiguous with parastyle by a narrow channel but low in vertical height as compared to other cusps. The metaconule is present postero-lingually, low in vertically height than metacone and larger than protocone. The premetaconule crista is U-shaped while postmetaconule crista is oval in shape. The overall shape of metaconule is like “W” due to distinct bifurcation between premetaconule crista and postmetaconule crista.

The paracone is inverted V-shaped structure present at antero-labial side of tooth. The paracone is extensively worn and form a dentinal islet antero-posteriorly. The enamel lining of paracone anterolabially directed forward and backward to form a very thick parastyle which is low in vertical height than the metastyle. The paracone has a very strong thick labial rib. The paracone is robust and corrugated in the middle of lingual side of the crown.

The metacone is also inverted V-shaped structure and higher than the metaconule. It is moderately worn and dentine is exposed. The metacone appear to be contiguous with metaconule through a narrow channel at posterior end. The postmetacrista is elongated in contrast to premetacrista. The enamel lining of metacone extends anteriorly and paracone posteriorly and outwardly to form a very strong and thick mesostyle. There is also a style present at the posterior extreme of cusp known as metastyle. The metacone has flat median rib.

The mesostyle and metastyle are contiguous at the base of metacone, prominently supporting the metacone. The anterior fossette between the protocone and paracone is hemispherical in shape and shallow. While the posterior fossette between metaconule and metacone is V-shaped and is bifurcated. The posterior side forms an isolated shallow groove in the posterior fossette. The transverse valley is open lingually but is quite narrow labially. The longitudinal valley is linear antero-posteriorly. A low entostyle is present at the base of premetaconule crista.

M^2

Some molars are excellently preserved [Figure 4.3(1)]. In general contour, these are almost square in outline. A well-developed pressure mark is present at the anterior as well as posterior side of the teeth. The cingulum is present anteriorly and it is absent posteriorly. The preprotocrista is comparatively longer than the postprotocrista. The wearing is more confined towards the extremities of cusp rather than in the axis. The metaconule is V-shaped structure. It is bifurcated at the posterior side of crown surface by a spur like structure. Its posterior half is broad longitudinally than the anterior one. It is moderately worn and dentine is exposed. It is contiguous with metacone posteriorly but low in vertical height. It is bounded by thick layer of enamel.

The paracone extends forward and folded backward anteriorly to produce a pillar like structure known as parastyle which is quite broad and thick proximally and distally. The paracone has very strong median rib, which is similar to parastyle in shape. An enamel complex is present which is connecting the postprotocrista to premetacrista. The enamel folding of metacone extends anteriorly and paracone posteriorly and outwardly to form very strong, thick and well separated mesostyle. The longitudinal valley is wavy and deep antero-posteriorly while transverse valley is open lingu-labially.

Lower dentition

P_2

The principal cuspids are well preserved. The anterior most cuspid protoconid is connected with hypoconid posteriorly forming proto-hypoconid complex. It is vertically higher than para, meta and entoconids. The paraconid is forming parastylid antero-lingually. The central lingual cuspid metaconid is somewhat prominent. The entoconid is making entostylid postero-lingually [Figure 4.3(2)].

P_3

It is long, low and quadrangular in general contour. The protoconid and hypoconid are equal in size forming proto-hypoconid complex labially. The paraconid is supported by a bifurcated parastylid lingually. The metaconid is bifurcated and connected lingually to para- and entoconids. The entoconid is supported lingually by entostylid. The longitudinal valley is wavy. The transverse valley is open labio-lingually [Figure 4.3(3)].

M_2

The preprotocristid is somewhat longer than postprotocristid. It is connected with premetacristid by an enamel complex. The prehypocristid and posthypocristid are equal in size. The hypoconid is supported by highly corrugated cingulum. The preentocristid slope posteriorly and backwardly directed to form low pillar like entostylid. At the lingual side of entoconid, the enamel lining is folded in the middle to form a flat median rib.

M_3

All four principal cuspids i.e. protoconid, hypoconid, metaconid and entoconid are clearly differentiated. The hypoconid looks like a protoconid and supported by cingulum ridges labially. The metaconid is vertically higher in the middle sloping down towards the anterior and posterior ends forming a spindle shape structure. It is supported by median rib which is quite broad proximally and narrows distally. A low mesostylid and prominent metastylid are present lingually. The entoconid is moderately worn and dentine is exposed having spindle shaped dentinal islets. It is low in vertical height than metaconid and it is supported by flat median rib. The hypoconulid is placed postero-labially [Figure 4.3(4)].

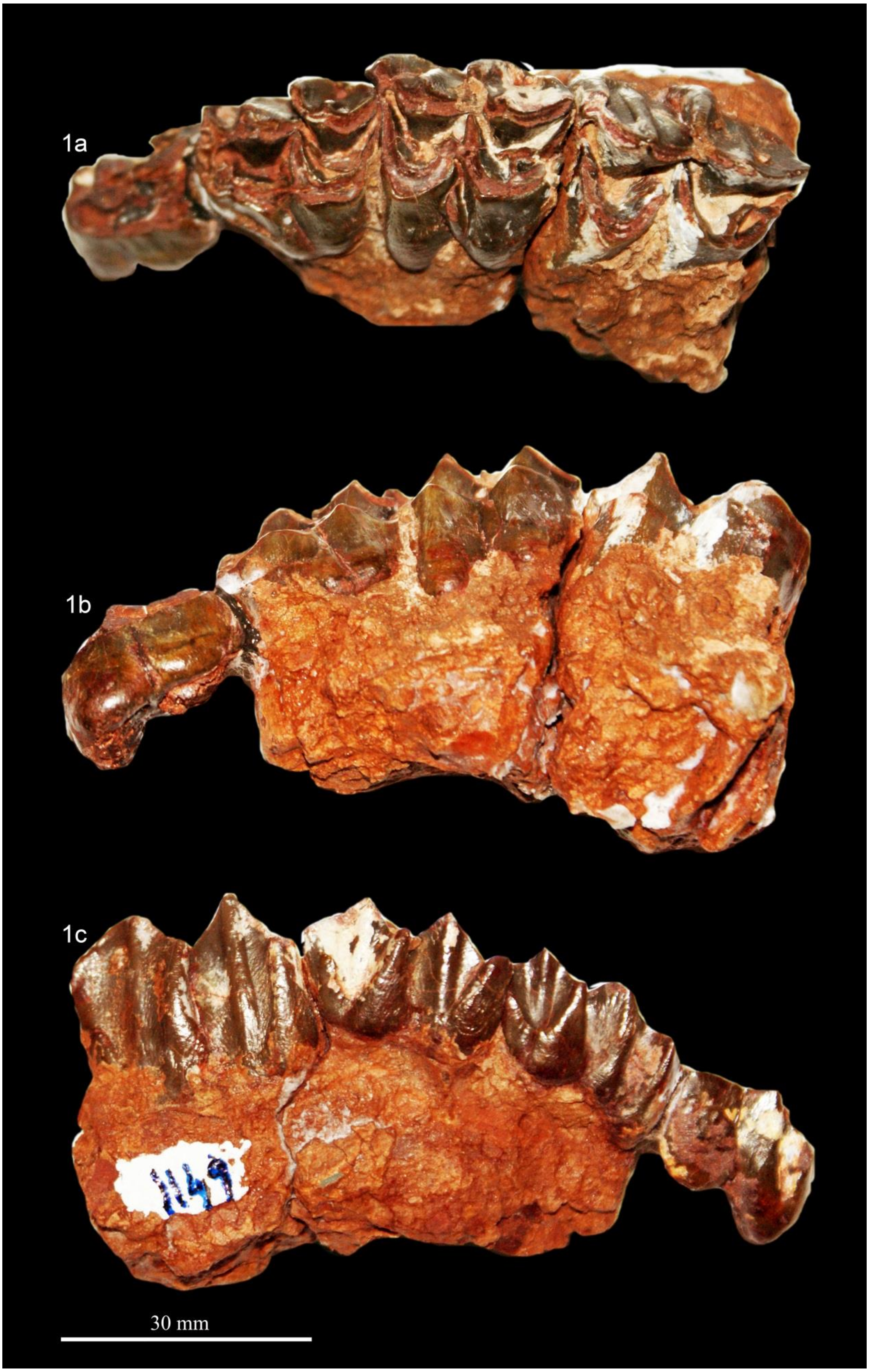


Figure 4.1: *Progiraffa exigua.* 1. GCUPC 1149/12, a left maxillary ramus with $DP^{2\text{-}4}$-M^1. a, occlusal view; b, lingual view; c, labial view (Scale bar 30 mm).

Figure 4.2: *Progiraffa exigua.* 1. GCUPC 1145/12, lP^2. 2. GCUPC 984/09, rDP^3. 3. PUPC 12/55, lM^1. 4. PUPC 88/10, lM^1. 5. GCUPC 1137/09, rM^1. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

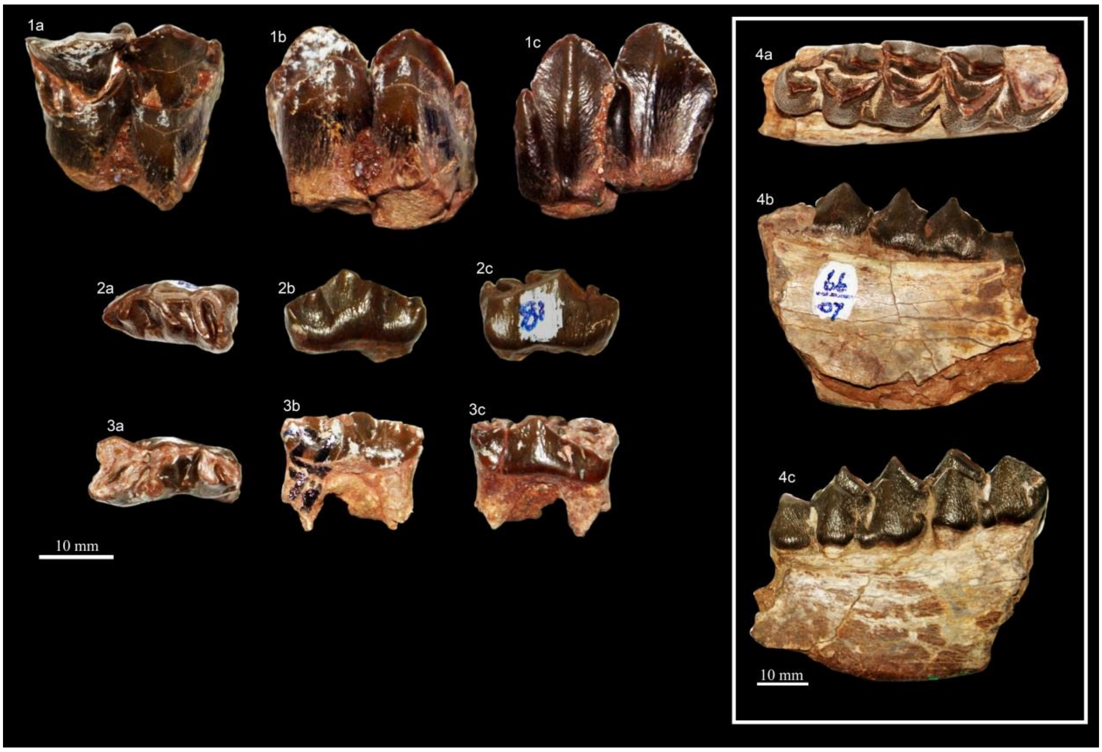


Figure 4.3: *Progiraffa exigua.* 1. GCUPC 1136/09, rM^2. 2. PUPC 81/91, rP_2. 3. PUPC 71/70, lP_3. 4. PUPC 66/07, $rM_{2\text{-}3}$. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

Table 4.1: Comparative measurements of the cheek teeth of the Siwalik *Progiraffa* in mm (millimeters) *the studied specimens. Referred data are taken from Lydekker (1883b), Pilgrim (1911), Colbert (1935), Bhatti (2005), Barry *et al*. (2005) and Khan *et al*. (2012).

Taxa	Number	Nature	Length (mm)	Width (mm)	W/L
P. exigua	GCUPC 1149/12*	DP^2	22.4	15.2	0.68
		DP^3	21.0	17.1	0.81
		DP^4	21.5	18.6	0.87
		M^1	26.4	20.5	0.78
	GCUPC 984/09*	DP^3	23.0	17.9	0.78
	GCUPC 1145/12*	P^2	20.3	15.1	0.74
	PUPC 12/55*	M^1	22.1	20.6	0.93
	PUPC 88/10*	M^1	22.1	20.9	0.95
	GCUPC1137/09*	M^1	22.5	20.7	0.92
	PUPC 84/77*	M^1	22.4	20.2	0.90
	GCUPC 1136/09*	M^2	25.5	21.8	0.85
	GCUPC 1177/09*	M^2	23.8	22.8	0.96
	GCUPC 1180/09*	M^2	24.0	23.5	0.98
	GCUPC 230/99*	M^2	23.9	23.2	0.97
	PUPC 81/91*	P_2	17.6	8.60	0.49
	PUPC 71/70*	P_3	19.4	9.30	0.48
	PUPC 66/07*	M_2	21.5	14.8	0.69
		M_3	32.0	14.4	0.45
	GSP-H 312	M^1	22.3	21.7	0.97
		M^2	24.0	25.9	1.08
	GSP-S 412	P_3	17.7	9.20	0.52
	GSI B 491	M_2	21.3	13.8	0.65
		M_3	27.2	12.9	0.47
	GSP-Y 41662	M_2	21.2	14.4	0.68
	GSP-H 208	M_3	32.1	14.5	0.45
P. sivalensis	GSIB 337	M^1	23.9	25.0	1.04
	GSIB 492	M_3	36.1	17.3	0.48
P. sp.	GSI B 95	M_2	21.5	14.8	0.69

Table 4.1 (continued)

Giraffokeryx punjabiensis	GSI B504	M^1	24.2	25.7	1.06
	GSI B505	M^2	30.2	28.2	0.93
	AMNH 19475	P^2	22.0	19.0	0.86
		M^1	22.0	24.0	1.09
		M^2	25.0	27.0	1.08
	AMNH 19472	M^1	23.0	22.0	0.96
		M^2	27.0	25.5	0.94
	AMNH 19334	M^1	25.5	25.0	0.98
		M^2	27.0	27.0	1.00
	AMNH 19930	M^1	26.5	28.0	1.06
	AMNH 19593	M^1	24.0	24.0	1.00
	AMNH 19320	M^2	29.0	28.5	0.98
	AMNH 19611	M^2	27.0	26.0	0.96
	AMNH 19632	M^2	28.0	24.0	0.86
	PUPC 66/95	M^1	26.0	28.0	1.08
		M^2	28.0	28.0	1.00
	PUPC 02/15	M^1	20.0	21.0	1.05
	PUPC 69/37	M^2	29.0	29.0	1.00
	PUPC 94/1	M^2	27.0	25.0	0.93
	PUPC 94/3	M^2	27.5	26.1	0.95
	AMNH 19849	P_2	16.0	9.0	0.56
		P_3	22.0	11.0	0.51
		M_2	22.0	16.0	0.73
		M_3	35.0	15.5	0.44
	PUPC 2002/06	P_2	16.0	9.0	0.56
		P_3	21.0	12.5	0.60
	GSI B 496	P_3	21.8	14.0	0.64
	GSI B 493	M_2	25.0	17.6	0.70
		M_3	36.0	16.6	0.46
	AMNH 19419	M_2	29.0	19.0	0.66
	AMNH 19320	M_2	27.0	15.0	0.56
	AMNH 19317	M_3	37.0	18.0	0.49

Table 4.1 (continued)

	AMNH 19335	M_3	39.0	20.0	0.51
	PUPC 02/12	M_3	34	18	0.53
	PUPC 02/15	M_3	23.5	17.5	0.74
	PUPC 02/19	M_3	27.1	19.0	0.70
Giraffa priscilla	PUPC 07/131	M^1	25.0	25.0	1.00
	PUPC 07/89	M^1	27.0	27.0	1.00
	PUPC 02/99	M^1	24.0	24.0	1.00
		M^2	25.0	28.0	1.12
	PUPC 02/9	M_3	40.0	17.0	0.43

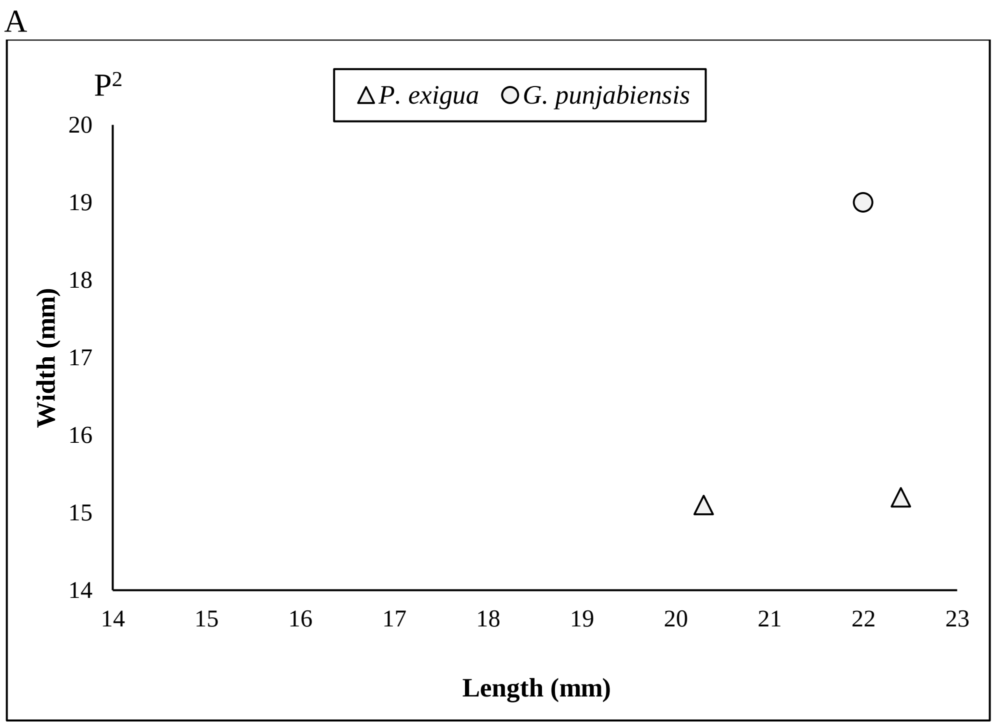


Figure 4.4: Scatter diagram showing dental proportions of upper second premolars of the Middle Miocene Siwalik giraffids. Referred data are taken from Lydekker (1883b), Pilgrim (1911), Colbert (1935), Bhatti (2005), Barry *et al*. (2005) and Khan *et al*. (2012).

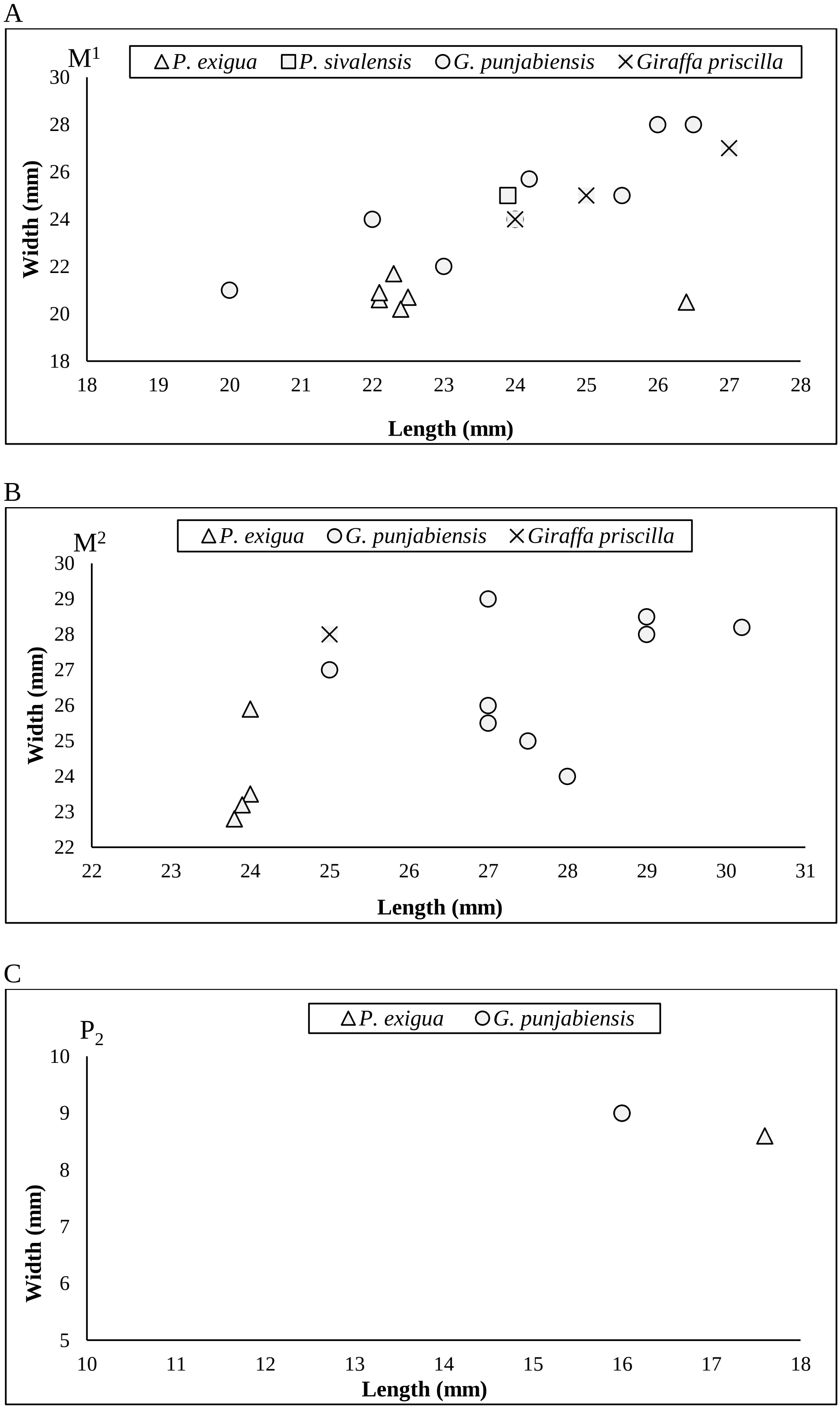


Figure 4.5: Scatter diagram showing dental proportions of the Middle Miocene Siwalik giraffids; A, upper first molars; B, upper second molars; C, lower second premolars. Referred data are taken from Lydekker (1883b), Pilgrim (1911), Colbert (1935), Bhatti (2005), Barry *et al*. (2005) and Khan *et al*. (2012).

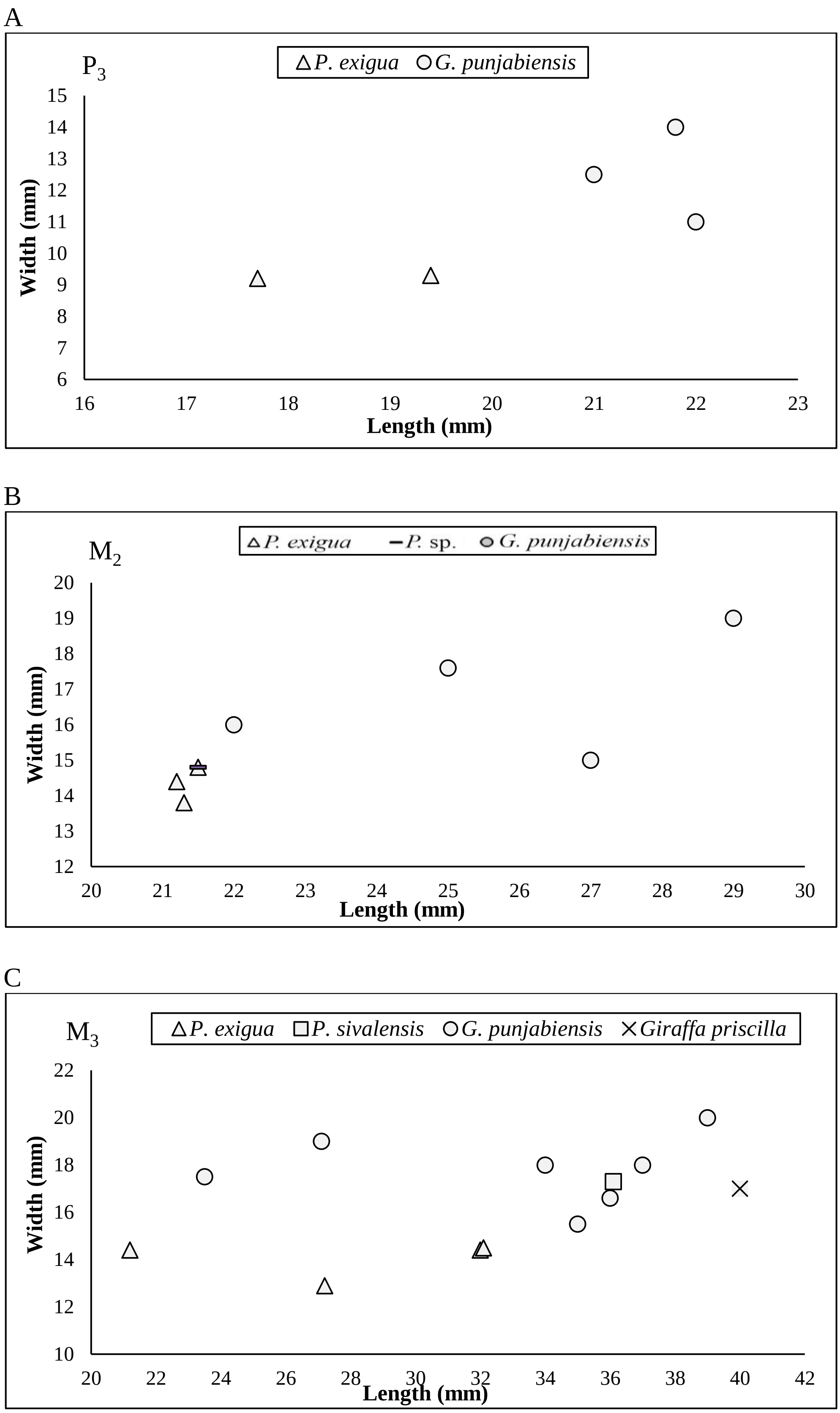


Figure 4.6: Scatter diagram showing dental proportions of the Middle Miocene Siwalik giraffids; A, lower third premolars; B, lower second molars; C, lower third molars. Referred data are taken from Lydekker (1883b), Pilgrim (1911), Colbert (1935), Bhatti (2005), Barry *et al*. (2005) and Khan *et al*. (2012).

Subfamily Giraffokerycinae Solounias, 2007

4.1.2 Genus *GIRAFFOKERYX* Pilgrim, 1910

Type species

Giraffokeryx punjabiensis Pilgrim, 1910

Generic diagnosis

Moderate-sized genus having brachyodont cheek teeth with rugose enamel sculpture. Length of limbs and feet is medium. Two pairs of ossicones are present, one projects from anterior extremities of the frontal bone and other pair is situated on the fronto-parietal region. The anterior horns are in front of the orbits, while posterior horns overhanging the temporal fossa (Pilgrim, 1910; Matthew, 1929; Colbert, 1933, 1935; Solounias, 2007).

Geographic distribution

Giraffokeryx is best known from the Siwaliks of India and Pakistan (Pilgrim, 1910; Bhatti, 2005; Bhatti *et al*., 2007a, 2012a; Khan *et al*., 2010), Dang Valley (Nepal), Belomechetskaia (Russian Federation), Fort Ternan (Kenya) and Turkey (Colbert, 1935; Churcher, 1970; Geraads, 1986a, Janis and Scott, 1987; Gentry and Hooker, 1988; Gentry, 1990; West *et al*., 1991; Pickford *et al.*, 2000; Geraads and Aslan, 2003). *Giraffokeryx* is recorded from Southern Asia, Africa and few Astaracian age localities of Europe (Gentry, 1990).

Included species

Giraffokeryx primaevus Churcher, 1970; *Giraffokeryx anatoliensis* Geraads and Aslan, 2003

Giraffokeryx punjabiensis Pilgrim, 1910

Lectotype

GSI B502, a third molar of the right maxilla.

Type locality

Chinji village (Lower Siwaliks), Chakwal district, the Punjab province, Pakistan (Colbert, 1935).

Stratigraphic range

Lower Siwaliks and the lower portion of the Middle Siwaliks (Chinji-basal Nagri, Daud Khel Fauna (Minawali, Punjab), Manchar (Sind, Yale GSP locality 4 and 15) (Pilgrim, 1910; Matthew, 1929; Colbert, 1935; Hussain and West, 1979; Raza *et al*., 1984; Bhatti, 2005; Khan *et al*., 2010; Bhatti *et al*., 2007a, 2012a).

Geographic distribution

Giraffokeryx punjabiensis is recorded from south Asia (Pilgrim, 1910; Colbert, 1935; Bhatti, 2005; Bhatti *et al*., 2007a, 2012a; Khan *et al*., 2010). It is also known from Eurasia and Greco-Iranian province (Kostopoulos and Sarac, 2005).

Specific diagnosis

The major cusps are in a straight line. Upper molars subhypsodont and large with prominent para- and mesostyles, stylids are weakly developed or absent. Entostyle and ectostylid are tiny or absent. The anterior rib is more prominent as compared to posterior one (Pilgrim, 1910, 1911; Colbert, 1935; Bhatti, 2005; Bhatti *et al*., 2012a).

New material (in parenthesis the inventory number and the locality name are given):

Upper dentition: lP^{3s} (GCUPC 1141/09, 1170/12 Chabbar Sayadan), rP^{3s} (GCUPC 1173/09, Bhelomar; GCUPC 1072/09, Wasnal), lP^4 (GCUPC 707/05, Chinji Rest House), rP^4 (GCUPC 1162/13, Chinji Rest House), a left maxillary ramus with P^4-M^1 (GCUPC 706/05, GCUPC 1162/13, Chinji Rest House), rM^1 (GCUPC 1185/12, Dhok Bun Amir Khatoon), lM^{2s} (GCUPC 1172/09, Bhelomar; GCUPC 1187/12, GCUPC 1188/12, Dhok Bun Amir Khatoon; GCUPC 1353/09, Chinji Rest House), rM^{2s} (GCUPC 1183/12, GCUPC 1184/12, Parrhewala; GCUPC 1167/12, Dhok Bun Amir Khatoon; GCUPC 1144/09, Bhelomar), a left maxillary ramus bearing M^{2-3} (GCUPC 1135/09, Chinji Rest House), rM^3 (GCUPC 1148/12, Dhok Bun Amir Khatoon).

Lower dentition: rP_2–M_1 (GCUPC 1161/12, Dhok Bun Amir Khatoon), rP_{2-3}(GCUPC 1140/12, Bhelomar), rP_3–M_3 (GCUPC 1165/13, Dhok Bun Amir Khatoon) lP_{3s} (GCUPC 1190/12, GCUPC 1171/12, Dhok Bun Amir Khatoon), rP_4 (GCUPC 1150/09, Ghungrilla; GCUPC 1175/13, Chinji Rest House), rM_1 (GCUPC 1152/12, Dhulian), lM_{2s} (GCUPC 1156/12, Ghungrilla; GCUPC 1146/12, Dial), rM_{2s} (GCUPC 1143/12, Phadial; GCUPC 720/05, Lava), lM_{3s} (GCUPC 959/08, Bhelomar; GCUPC 1182/12, Dhulian), rM_3 (GCUPC 1181/12, Lava; GCUPC 419/01, Dial).

Description

Upper dentition

P^3

The premolars are excellently preserved, moderately worn with dentine mostly exposed from the crown surface [Figure 4.7(1-3)]. The cingulum is present labio-lingually but it is quite thin antero-posteriorly. A thick layer of enamel with shiny surface can be observed all around the crown surface. The fossette is quite large, shallow and crescent shape. The protocone is present antero-lingually but its preprotocrista is longer than postprotocrista. The enamel border is thick and wrinkled. It is contiguous with metaconule posteriorly but low in vertical height and is supported by a thick layer of cingular ridges.

There is no clear cut demarcation between the metaconule and the protocone. These cones are appressed to form a continuous proto-metaconule complex. It is quite difficult to distinguish between the protocone and metaconule. The enamel of paracone is thick and crenulated and it is folded antero-labially to form a parastyle. It is narrow distally and broad proximally.

P^4

The premolars are half-moon like outline. [Figure 4.7(4-6)]. These are finely preserved, half worn and dentine is clearly visible. A short spur projects in median fossette posteriorly. The occlusal outline of the premolar is nearly rectangular, being much broader transversely than long. The protocone is half worn and dentine is exposed forming an oval shaped dentinal islet. The protocone is attached with paracone by narrow channel but low in vertical height than paracone. A preprotocrista unites a protocone with a parastyle. The metaconule is present at the posterior side of protocone. The protocone and metaconule are completely worn from the crown surface. These two cones are closely appressed therefore they form an unbroken island due to extensive wearing. The protocone is supported by protostyle which is united to form large supporting structure at the palatal side of tooth.

The paracone is present antero-labially. It is pushed out to form a thick pillar like parastyle. The metacone is connected with the metaconule with a narrow channel. It is pushed outward to form a pillar like structure called metastyle, which is quite low in vertical height than parastyle.

M^1

The teeth are almost square in outline [Figure 4.7(6-7)]. The enamel surface is quite thick, shiny and corrugated. A thin layer of cement is present labio-lingually. All the four principal cusps are well preserved in the upper first molar. The protocone is V-shaped, half worn and dentine is exposed forming a V-shaped dentinal islets. The enamel lining of protocone is continuous antero-posteriorly, thus dividing the tooth into two equal halves. The protocone is bounded by abundant enamel and supported by protostyle. The metaconule is similar in shape and size to protocone. A thin layer of cement is present at the lateral margin of metaconule.

The paracone is inverted V-shaped structure. Its enamel border is shiny and crenelated. The enamel lining of paracone directed forward and backward to form a very thick, pillar like structure parastyle antero-labially. The metacone is also inverted V-shaped and it is vertically higher than metaconule. It is almost worn showing a lingual dentinal islet. The enamel lining of prematacrista extends anteriorly and postparacrista posteriorly and outwardly to form a very strong and thick mesostyle, which is wider at base but damaged at summit of the crown perhaps due to some pressure. The paracone and metacone are provided with thin pillar like median ribs labially. Both fossettes are V-shaped but filled with thin layer of cement. Transverse valley is linear and shallow, while longitudinal valley is wavy and deep.

M^2

The antero-posterior contact facets are similar, indicating the second molars in molar series [Figures 4.8(1-6), 4.9(1-3)]. Cingulum is present all around the crown but thick and more prominent anteriorly. The four principal cusps are well differentiated. The premetaconule crista is U-shaped while postmetaconule crista is somewhat V-shaped. The metaconule looks like “W” due to distinct bifurcation between the premetaconule crista and postmetaconule crista. The metaconule is contiguous with metacone through a narrow channel on the posterior end.

The anterior fossette between the protocone and paracone is crescentic-shaped and deep. While the posterior fossette between the metaconule and the metacone is wide and narrow. The transverse valley is straight and open labio-lingually. The longitudinal valley is irregular.

M^3

The molars are well-preserved and in middle wear [Figure 4.9(3-4)]. The cingulum is quite thick all around the crown surface. The paracone is robust in the middle having a thick keel like structure called parastyle, which is thick and broad proximally as well as distally. The enemal layer of paracone is quite thick lingually but thin labailly. The metacone is comparatively less worn than paracone. The enamel lining of the metacone is thick, shiny and V-shaped in outline. The metastyle is comparatively heavy and bulky. It is present at the posterior extreme of cusp. The enamel lining of metacone at the anterior labial side is directed forward and backward to form a thick small pillar like structure known as mesostyle. The mesostyle is continuous with the cingulum at the base of the crown forming a definite shelf like structure. The metacone has incipiently developed median rib. The median rib of paracone is quite thick and pillar like structure.

Lower dentition

Mandible

The mandible fragments are fragile [Figure 4.10(1, 3)]. The mandibular ramus is narrow anteriorly and broad posteriorly. It is narrow labio-lingually. The ventral edge of the mandible fragment is thick.

P_2

The paraconid is present anteriorly. It is vertically lower than meta- and entoconids. These all cuspids are slightly worn and are supported by the cingulum and cingular ridges antero-lingually. The parastylid and entostylid are conspicuous in both specimens. The dental morphology in both specimens is similar except the size of the crown [Figure 4.10(1-2)].

P_3

The premolars are supported by the thick layer of cingulum labio-lingually [Figures 4.10(1-3), 4.11(1-2)]. The paraconid is supported by a thin parastylid antero-lingually. The metaoconid and entoconid are closely appressed forming a complex at the apex of the crown surface. The entoconid is provided with pillar like entostylid which runs lingually forming oval shape transverse lamellae. The antero-labially protoconid is vertically higher than postero- labially hypoconid.

P_4

The teeth are quadrangular in shape, almost worn from summit of the crown [Figures 4.10(1, 3), 4.11(3-4)]. The protoconid and hypoconid are lower in vertical height than the metaconid and the entoconid. The crown is surrounded by a thick layer of cingulum lingu-antero-posteriorly. The cingulum is weakly developed labially. The fossette is oval in shape in between the protoconid and metaconid. The metaconid is supported by the metastylid which is incipiently produced. The fourth premolar is almost moralized and its principal cuspids are similar in its outline to that of first molar.

M_1

The lower first molars are excellently preserved and rectangular in shape. A well-developed cingulum is present labially but it is incipiently developed lingually. The enamel is thick, shiny and corrugated. The cingulum is prominent at the base of protoconid [Figures 4.10(1, 3), 4.11(5)]. The preprotocristid and postprotocristid are almost equal in size. The prehypocristid is shorter than the posthypocristid. The enamel lining of metaconid folded antero-backwardly to form a thin mesostylid. The preentocristid is much smaller and wavy than postentocristid. The postentocristid extends posteriorly to form a thin entostylid. The metastylid is not prominent. The antero-posterior median ribs are thin.

M_2

The molars are excellently preserved and quadrangular in general contour [Figures 4.10(3), 4.11(6), 4.12(1-2]. The teeth are narrow crowned and moderately worn exposing the dentine on the apices of the crown surface. The protoconid is provided with strong cingular ridges. The hypoconid is similar to that of protoconid but its prehypocristid is shorter than the posthypocristid. The enamal layer of the metaconid is connected with the entoconid. The entoconid is supported by a thin median rib. The antero-posterior fossettes are crescent shape and deep. The longitudinal valley is sagittal between the antero-posterior cuspids.

M_3

The molars are four cuspid teeth with hypoconulid present posteriorly [Figures 4.10(3), 4.12(3-5)]. The teeth are excellently preserved and moderately worn so that dentals islets develop in all the principal cuspids including hypoconulids. The cingulum is fairly developed all around the crown. It is quite thick labially and weakly developed lingually. The cingulum present antero-posteriorly is quite large forming a shelf like structure. These teeth are elongated and narrow crowned. A small ectostylid is present at the base in between the protoconid and hypoconid. The mesostylid and median ribs are very week. The entoconid is continuous with the hypoconulid which is V-shaped, robust and pillar like structure. Its internal limb is attached with posthypocristid while external limb is joined with postentocristid. Such distinctly arranged position of this cuspid indicated that it is the last molar in the numerical seriation, so it is also referred to as heel.

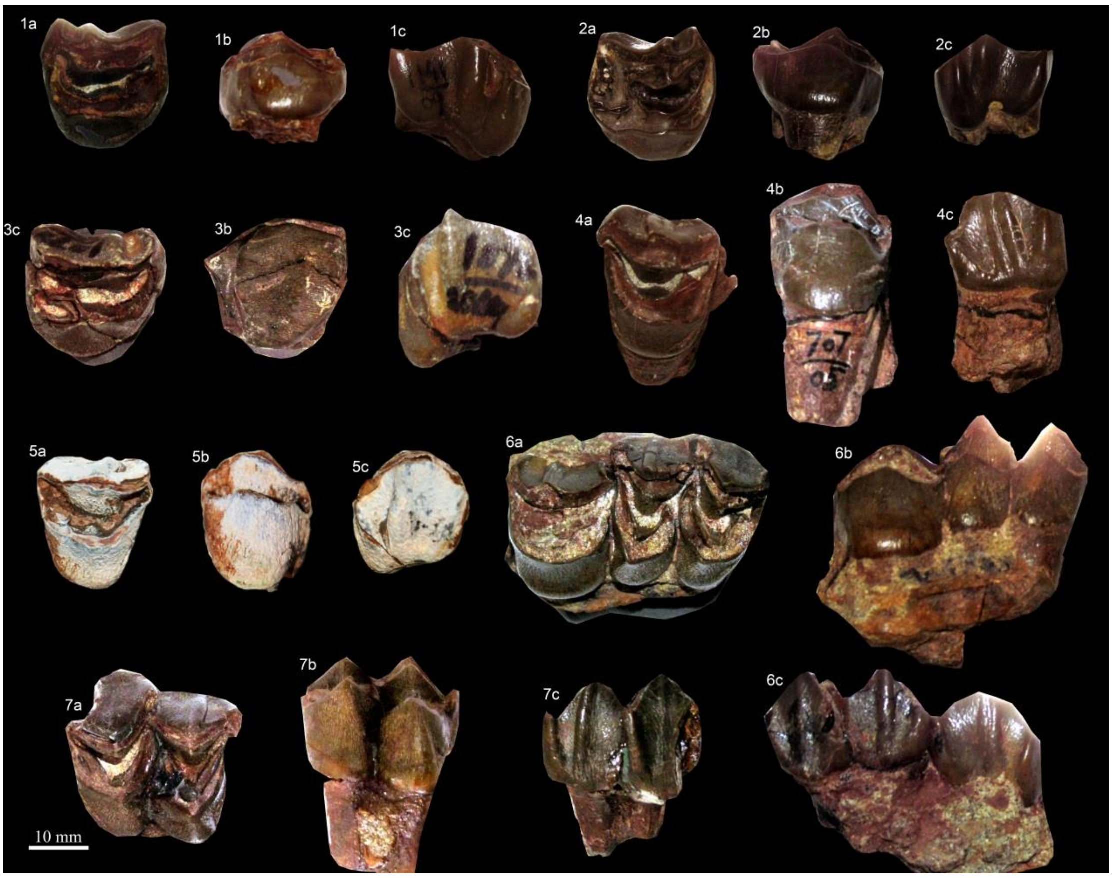


Figure 4.7: *Giraffokeryx punjabiensis*. 1. GCUPC 1141/09, lP^3. 2. GCUPC 1173/09, rP^3. 3. GCUPC 1072/09, rP^3. 4. GCUPC 707/05, lP^4. 5. GCUPC 1162/13, rP^4. 6. GCUPC 706/05, left maxillary ramus with P^4-M^1. 7. GCUPC 1185/12, rM^1. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

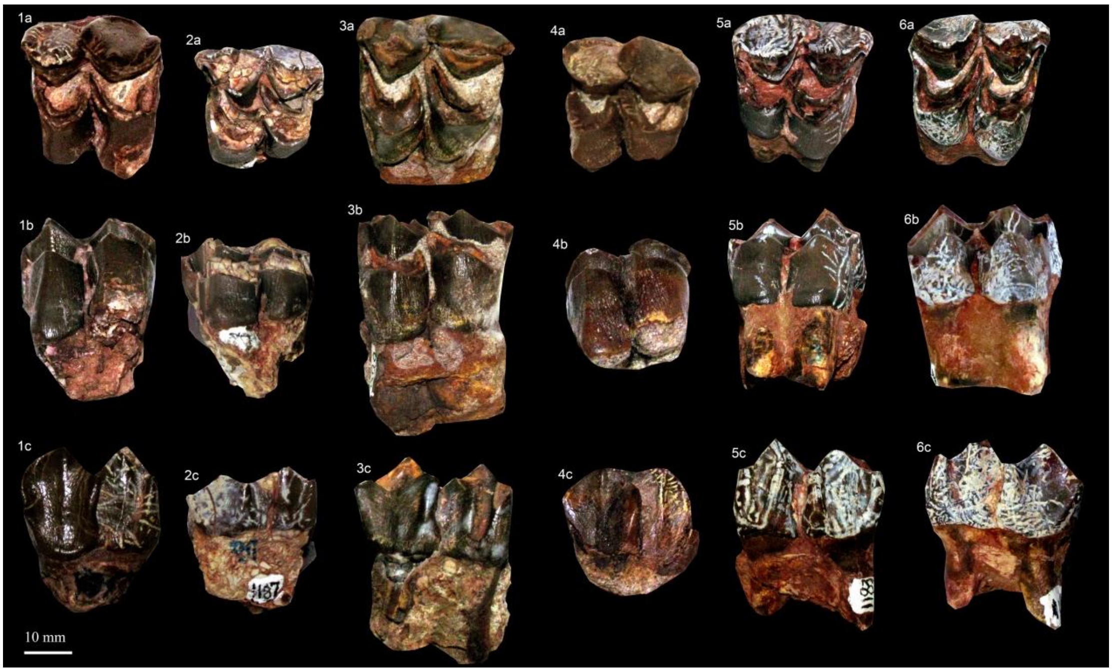


Figure 4.8: *Giraffokeryx punjabiensis*. 1. GCUPC 1172/09, lM^2. 2. GCUPC 1187/12, lM^2. 3. GCUPC 1188/12, lM^2. 4. GCUPC 1353/09, lM^2. 5. GCUPC 1183/12, rM^2. 6. GCUPC 1184/12, rM^2. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

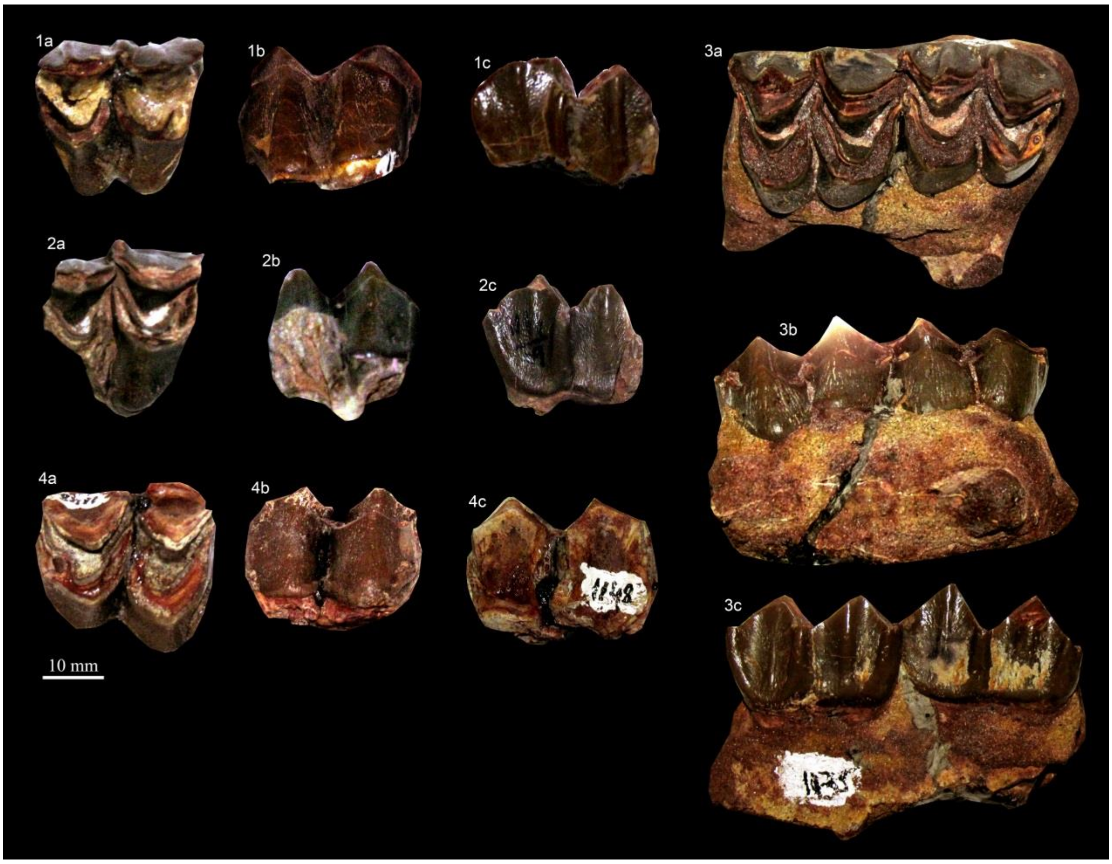


Figure 4.9: *Giraffokeryx punjabiensis*. 1. GCUPC 1167/12, rM^2. 2. GCUPC 1144/09, rM^2. 3. GCUPC 1135/09 left maxillary ramus bearing M$^{2\text{-}3}$. 4. GCUPC 1148/12, rM^3. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

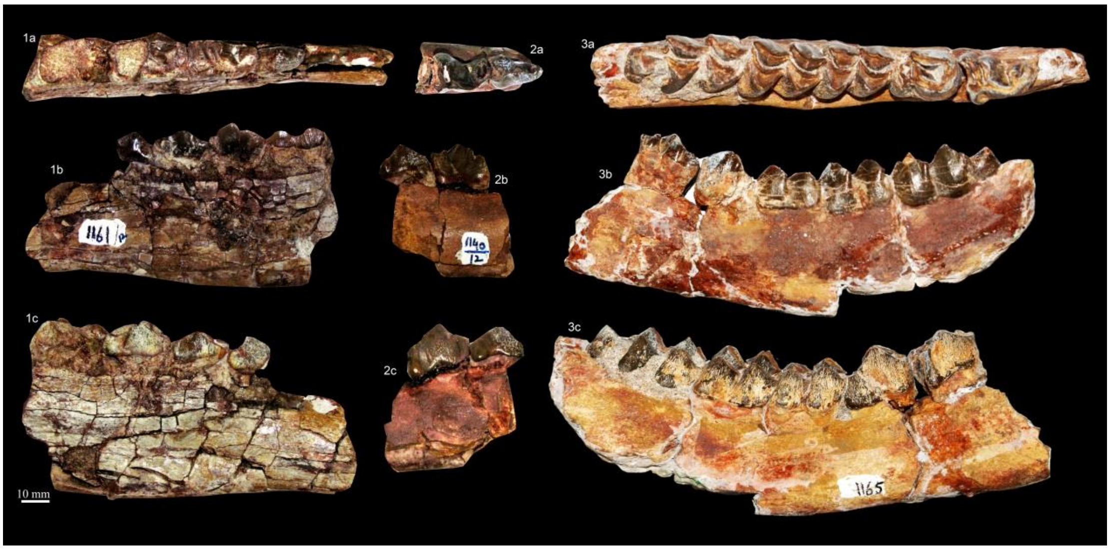


Figure 4.10: *Giraffokeryx punjabiensis*. 1. GCUPC 1161/12, rP$_2$–M$_1$. 2. GCUPC 1140/12, rP$_{2\text{-}3}$. 3. GCUPC 1165/13, rP$_3$–M$_3$. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

Figure 4.11: *Giraffokeryx punjabiensis*. 1. GCUPC 1190/12, lP_3. 2. GCUPC 1171/12, lP_3. 3. GCUPC 1150/09, rP_4. 4. GCUPC 1175/13, rP_4. 5. GCUPC 1152/12, rM_1. 6. GCUPC 1156/12, lM_2. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

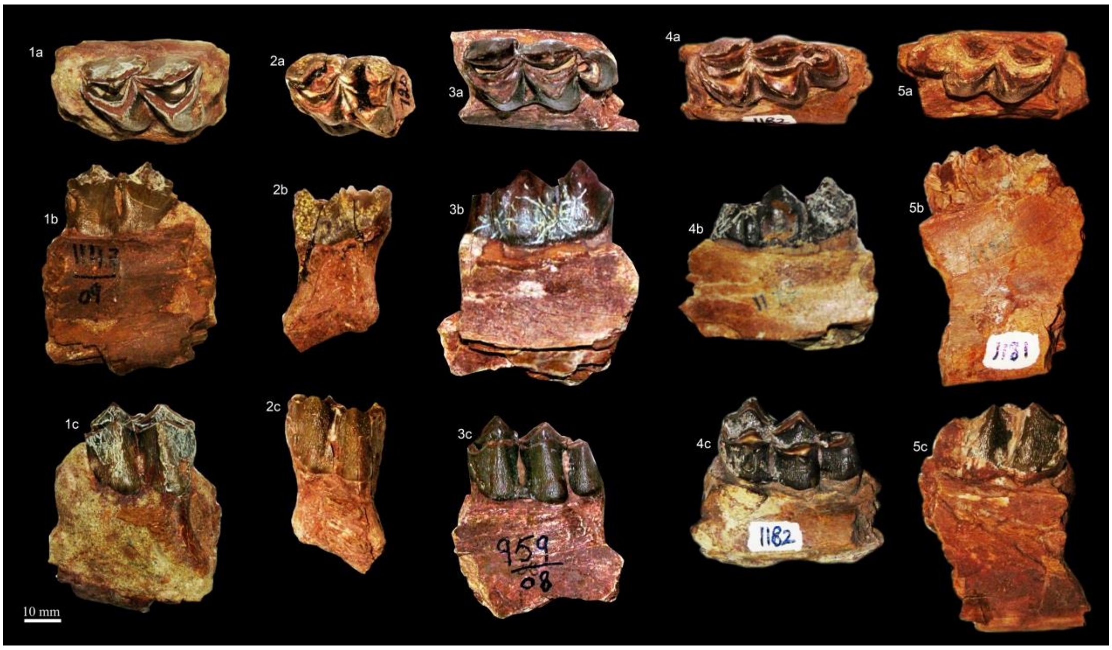


Figure 4.12: *Giraffokeryx punjabiensis*. 1. GCUPC 1143/12, rM_2. 2. GCUPC 720/05, rM_2. 3. GCUPC 959/08, lM_3. 4. GCUPC 1182/12, lM_3. 5. GCUPC 1181/12, rM_3. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

Table 4.2: Comparative dental measurements of the cheek teeth of the Siwalik *Giraffokeryx* in mm (millimeters) * the studied specimens. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Bhatti (2005), and Bhatti *et al.* (2012a).

Taxa	**Number**	**Nature**	**Length (mm)**	**Width (mm)**	**W/L**
G. punjabiensis	GCUPC 1141/09*	P^3	22.5	21.7	0.96
	GCUPC 1170/12*	P^3	19.5	18.2	0.93
	GCUPC 1173/09*	P^3	22.7	21.4	0.94
	GCUPC 1072/09*	P^3	22.5	19.4	0.86
	GCUPC 707/05*	P^4	19.3	23.5	1.05
	GCUPC 1162/13*	P^4	19.5	20.5	1.22
	GCUPC 706/05*	P^4	19.3	23.2	1.20
		M^1	26.2	27.1	1.03
	GCUPC 1185/12*	M^1	27.5	28.0	1.02
	GCUPC 1172/09*	M^2	27.5	28.3	1.03
	GCUPC 1187/12*	M^2	28.4	26.3	0.93
	GCUPC 1188/12*	M^2	29.5	27.1	0.92
	GCUPC 1353/09*	M^2	26.1	26.7	1.02
	GCUPC 1183/12*	M^2	27.3	25.7	0.94
	GCUPC 1184/12*	M^2	29.4	28.1	0.96
	GCUPC 1167/12*	M^2	27.2	25.1	0.92
	GCUPC 1144/09*	M^2	24.1	26.2	1.09
	GCUPC 1135/09*	M^2	26.7	25.3	0.95
		M^3	25.0	25.5	1.02
	GCUPC 1148/12*	M^3	27.3	27.9	1.02
	GCUPC 1161/12*	P_2	16.1	9.1	0.57
		P_3	21	12.6	0.60
		P_4	22.3	14.1	0.63
		M_1	23	16.8	0.73
	GCUPC 1140/12*	P_2	18	10	0.56
		P_3	20	12.5	0.63
	GCUPC 1165/13*	P_3	23.5	16.2	0.69
		P_4	23.2	15.1	0.65

Table 4.2 (continued)

	M_1	24.1	17.3	0.72
	M_2	25.5	18.1	0.71
	M_3	36.1	17.8	0.49
GCUPC 1190/12*	P_3	20.1	11.4	0.57
GCUPC 1171/12*	P_3	20.5	12.1	0.59
GCUPC 1150/09*	P_4	24.0	15.0	0.63
GCUPC 1175/13*	P_4	22.5	15.5	0.69
GCUPC 1152/12*	M_1	27.3	17.4	0.64
GCUPC 1156/12*	M_2	29.0	20.0	0.69
GCUPC 1146/12*	M_2	29.5	20.3	0.69
GCUPC 1143/09*	M_2	29.5	18.2	0.62
GCUPC 720/5*	M_2	25.0	17.5	0.70
GCUPC 959/08*	M_3	37.6	17.3	0.46
GCUPC 1182/12*	M_3	37.8	17.1	0.45
GCUPC 1181/12*	M_3	35.4	16	0.45
GCUPC 419/01*	M_3	35.0	16.0	0.46
GSI B510	P^3	21.6	22.5	1.04
AMNH 19475	P^3	20.5	20.0	0.98
	P^4	17.5	21.0	1.20
	M^1	22.0	24.0	1.09
	M^2	25.0	27.0	1.08
	M^3	24.5	26.0	1.06
AMNH 19930	P^3	22.0	20.0	0.91
	P^4	19.5	23.5	1.21
	M^1	26.5	28.0	1.06
AMNH 19311	P^3	19.0	17.5	0.92
	P^4	15.0	18.0	1.20
	M^1	23.0	22.0	0.95
PUPC 94/11	P^3	23.0	22.0	0.96
GSI B509	P^4	20.6	24.7	1.20
AMNH 19325	P^4	18.0	24.0	1.33
	M^2	29.5	27.0	0.92

Table 4.2 (continued)

		M^3	27.5	28.0	1.02
	AMNH 19330	P^4	17.0	23.0	1.35
	PUPC 94/12	P^4	20.0	24.0	1.20
	GSI B504	M^1	24.2	25.7	1.06
	AMNH 19593	M^1	24.0	24.0	1.00
	AMNH 19334	M^1	25.5	25	0.98
		M^2	27.0	27	1.00
	PUPC 66/95	M^1	26.0	28.0	1.08
	PUPC 94/07	M^1	25.0	17.0	0.68
	PUPC 02/157	M^1	20.0	21.0	1.05
	GSI B505	M^2	30.2	28.2	0.93
	AMNH 19320	M^2	29.0	28.5	0.98
	AMNH 19611	M^2	27.0	26.0	0.96
	AMNH 19632	M^2	28.0	24.0	0.86
	AMNH 19623	M^2	27.0	29.0	1.07
	AMNH 19327	M^2	24.0	26.0	1.08
	AMNH 19632	M^3	23	23.5	1.02
	AMNH 19472	M^2	27.0	25.5	0.94
		M^3	25.0	25.0	1.00
	PUPC 69/37	M^2	29.0	29.0	1.00
	PUPC 94/1	M^2	27.0	25.0	0.93
	PUPC 94/02	M^2	26.0	26.4	1.02
	PUPC 02/13	M^2	27.1	27	1.00
	PUPC 94/3	M^2	27.5	26.1	0.95
	PUPC 66/95	M^2	28.0	28.0	1.00
		M^3	27.0	28.0	1.04
	GSI B502	M^3	30.3	36.3	1.20
	AMNH 19587	P_2	18.0	9.0	0.50
		P_3	20.5	12.0	0.59
		P_4	24.0	15.0	0.63
		M_1	24.0	16.0	0.67
		M_2	25.0	17.0	0.68

Table 4.2 (continued)

		M_3	37.0	17.0	0.46
	AMNH 19849	P_2	16.0	9.0	0.56
		P_3	22.0	11.0	0.51
		P_4	19.0	11.5	0.61
		M_1	22.0	14.5	0.66
		M_2	22.0	16.0	0.73
		M_3	35.0	15.5	0.44
	PUPC 2002/06	P_2	16.0	9.0	0.56
		P_3	21.0	12.5	0.60
		P_4	23.0	14.5	0.63
	GSI B 496	P_3	21.8	14.0	0.64
	AMNH 19323	P_3	20.0	12.0	0.60
		P_4	22.0	14.5	0.66
		M_1	22.5	16.0	0.71
		M_2	25.0	18.0	0.72
		M_3	33.0	17.0	0.52
	GSI B 495	P_4	23.7	14.0	0.59
	AMNH 19329	P_4	23.0	15.0	0.65
	AMNH 19324	P_4	22.0	15.5	0.70
		M_1	25.5	17.5	0.69
		M_2	27.0	19.0	0.70
		M_3	38.0	17.0	0.45
	AMNH 19419	M_2	29.0	19.0	0.66
	AMNH 19593	M_1	24.0	16.0	0.67
	AMNH 19320	M_1	27.0	16.0	0.59
		M_2	27.0	15.0	0.56
	AMNH 19332	M_1	25.0	16.0	0.62
		M_2	26.0	18.0	0.69
	GSI B 493	M_2	25.0	17.6	0.70
		M_3	36.0	16.6	0.46
	AMNH 19317	M_3	37.0	18.0	0.49
	AMNH 19335	M_3	39.0	20.0	0.51

Table 4.2 (continued)

	PUPC 02/12	M_3	34	18	0.53
	PUPC 02/15	M_3	23.5	17.5	0.74
	PUPC 02/19	M_3	27.1	19.0	0.70
G.aff. punjabiensis	E 369	P_3	22.0	13.1	0.60
		P_4	21.4	15.0	0.70
		M_1	23.0	17.8	0.77
		M_2	24.8	17.7	0.71
		M_3	35.2	16.3	0.46
Progiraffa exigua	H 312	P^3	18.5	15.1	0.82
		M^1	22.3	21.7	0.97
		M^2	24.0	25.9	1.08
		M^3	24.3	23.7	0.98
	H 664	M^3	26.7	29.1	1.09
	S 412	P_3	17.7	9.20	0.52
	Y 41662	M_2	21.2	14.4	0.68
	H 208	M_3	32.1	14.5	0.45
	GSI B. 491	M_2	21.3	13.8	0.65
		M_3	27.2	12.9	0.47
Progiraffa sivalensis	GSI B. 492	M_3	36.1	17.3	0.48
Giraffa priscilla	PUPC 02/99	P^3	19.0	18.0	0.95
		P^4	19.5	21.0	1.08
		M^1	24.0	24.0	1.00
		M^2	25.0	28.0	1.12
	PUPC 02/9	M_3	40.0	17.0	0.43

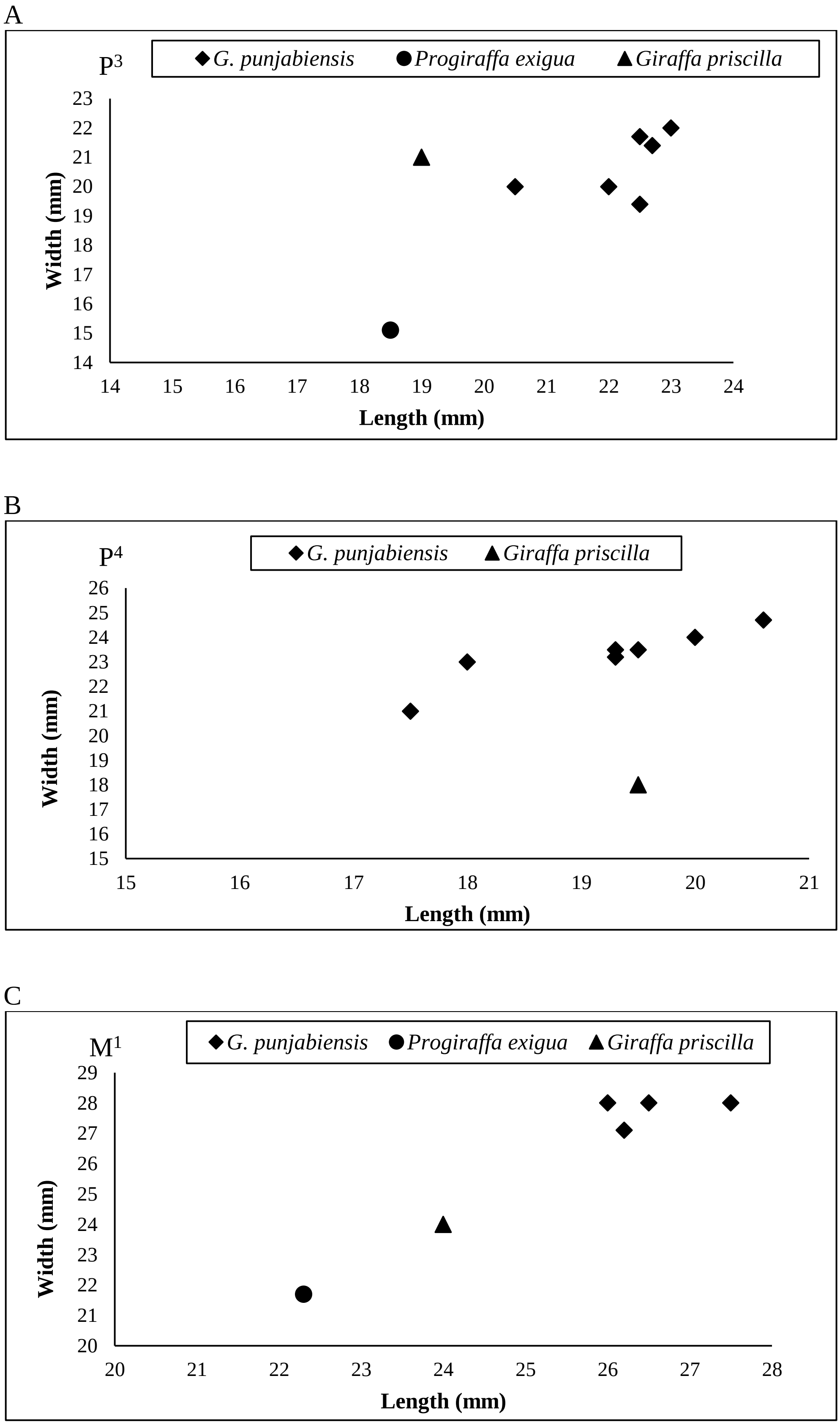


Figure 4.13: Scatter diagram showing dental proportions of the Siwalik *Giraffokeryx* species, *Progiraffa* species and *Giraffa priscilla*; A, upper third premolars; B, upper fourth premolars; C, upper first molars. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Bhatti (2005), and Bhatti *et al.* (2012a).

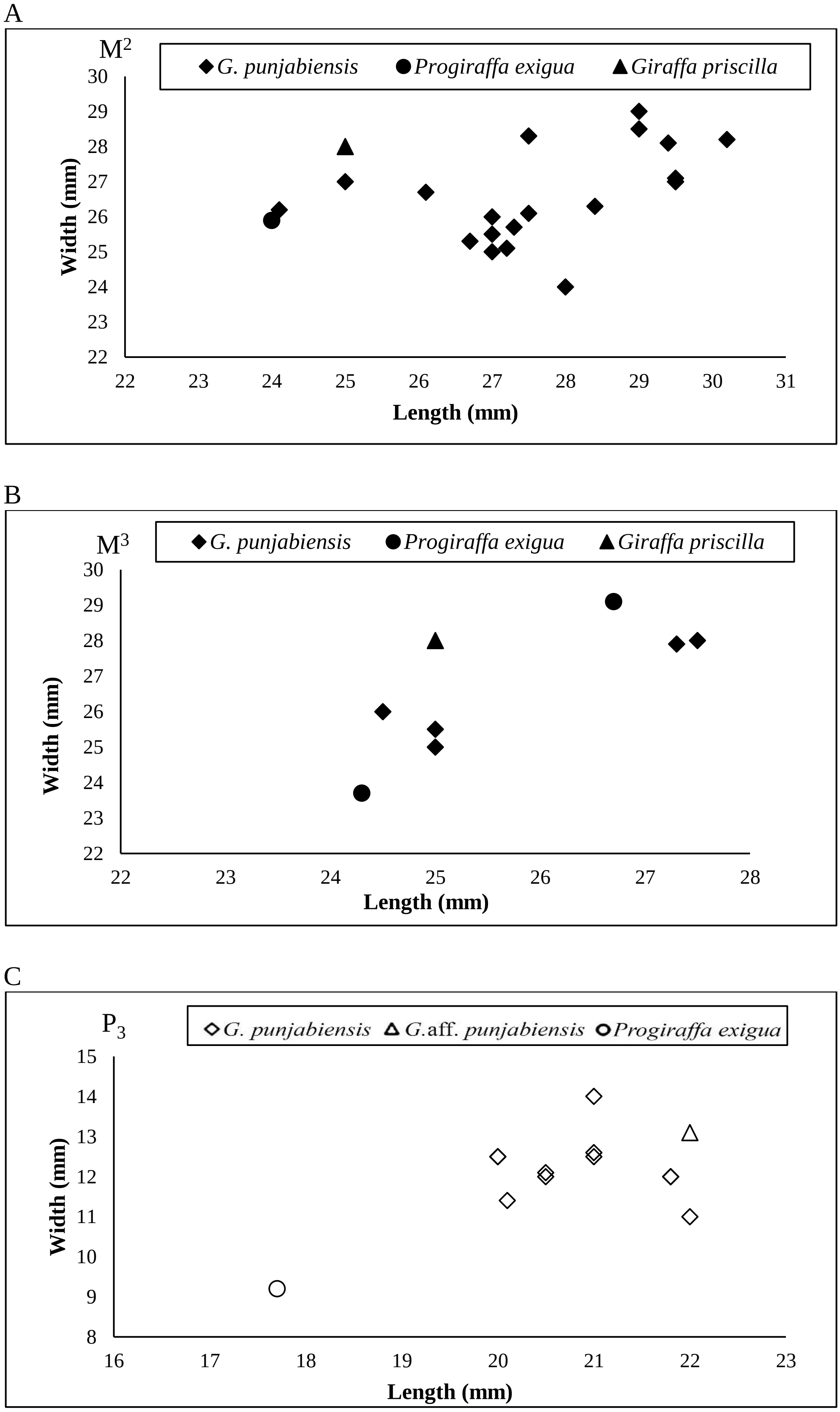
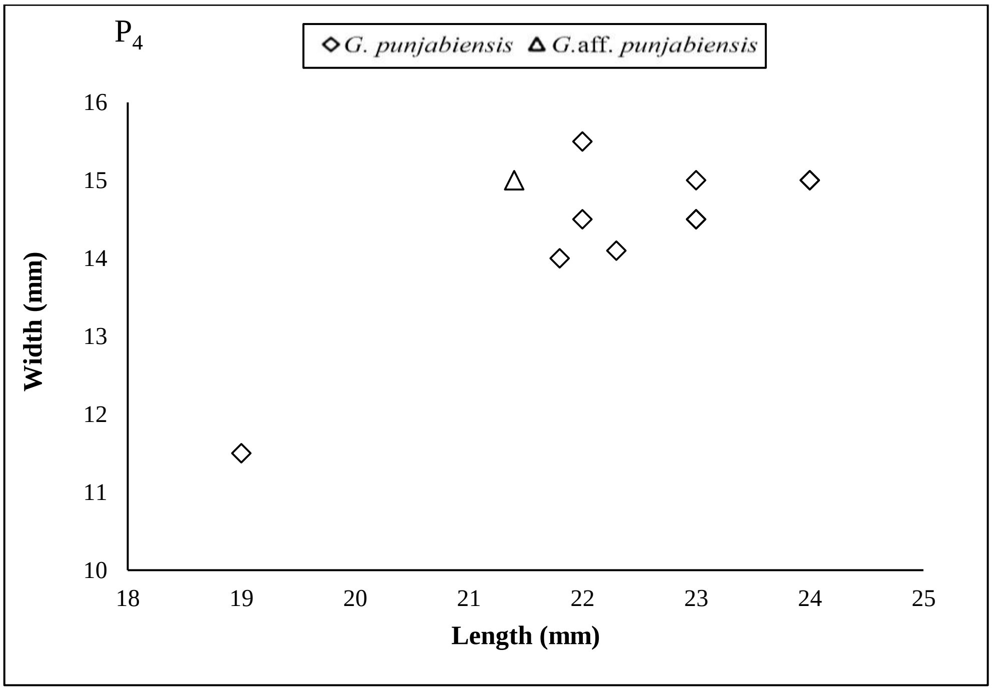


Figure 4.14: Scatter diagram showing dental proportions of the Siwalik *Giraffokeryx* species, *Progiraffa* species and *Giraffa priscilla*; A, upper second molars; B, upper third molars; C, lower third premolars. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Bhatti (2005), and Bhatti *et al.* (2012a).

A



B

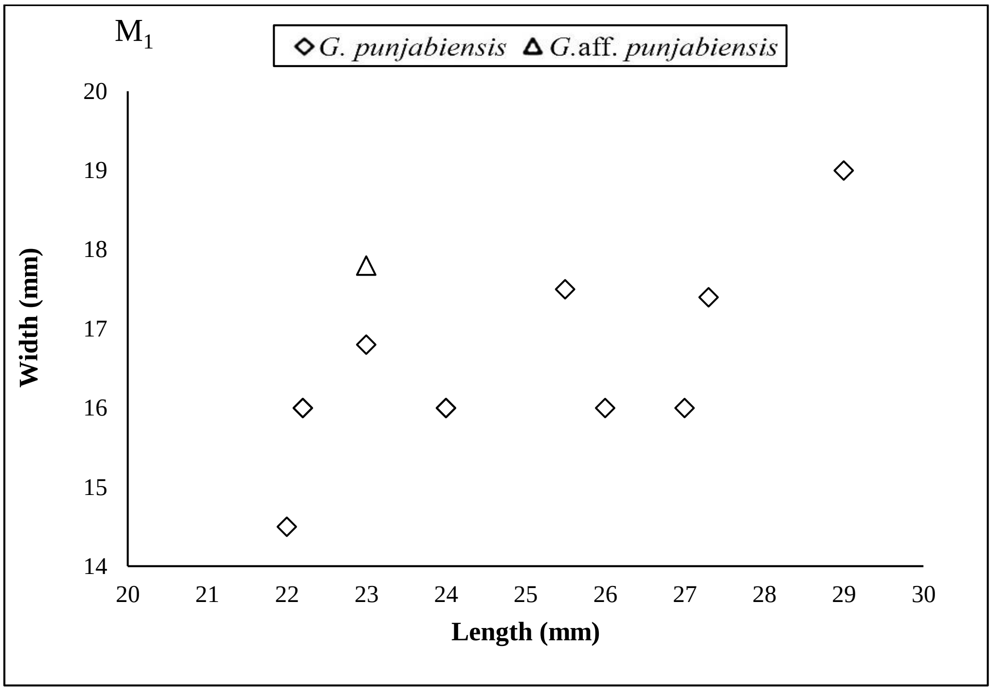
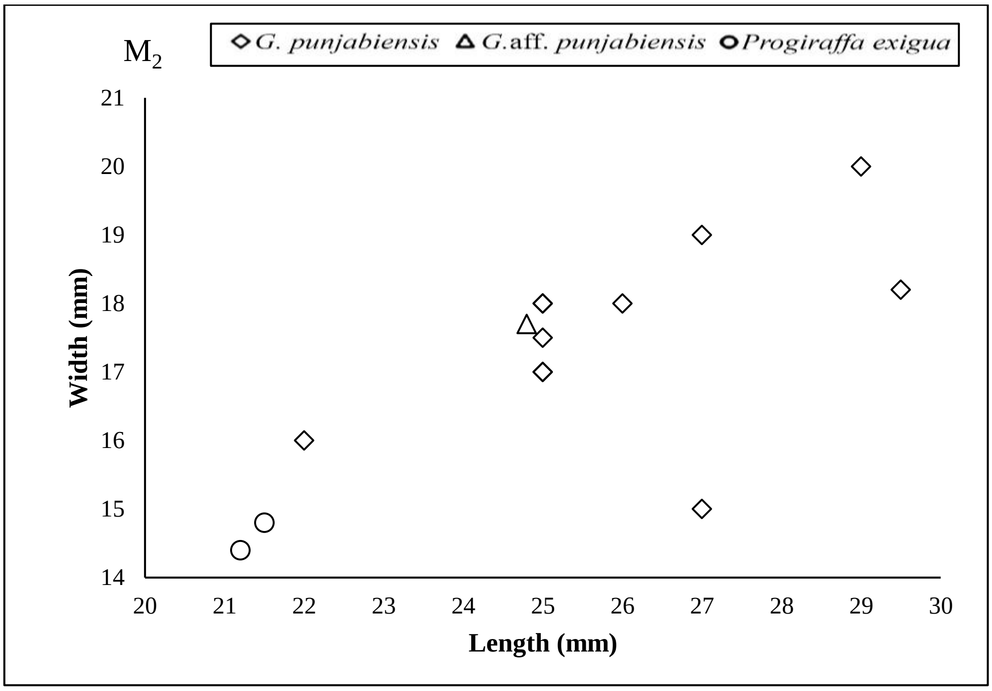


Figure 4.15: Scatter diagram showing dental proportions of the Siwalik *Giraffokeryx* species, *Progiraffa* species and *Giraffa priscilla*; A, lower fourth premolars; B, lower first molars. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Bhatti (2005), and Bhatti *et al.* (2012a).

A



B

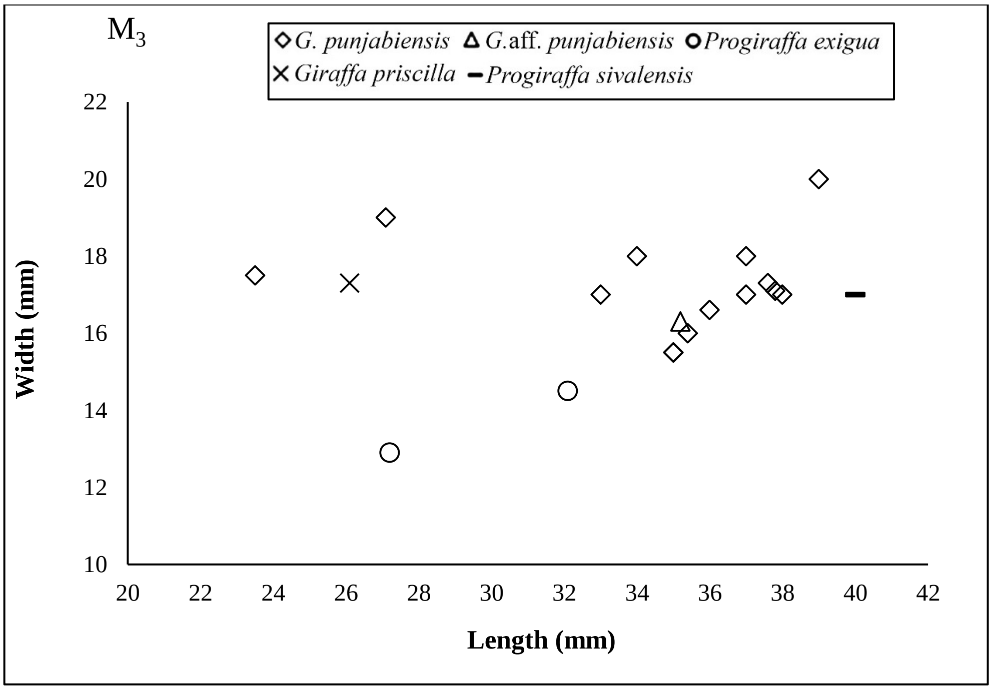


Figure 4.16: Scatter diagram showing dental proportions of the Siwalik *Giraffokeryx* species, *Progiraffa* species and *Giraffa priscilla*; A, lower second molars; B, lower third molars. Referred data are taken from Pilgrim (1911), Colbert (1935), Gentry (1990), Barry *et al.* (2005), Bhatti (2005), and Bhatti *et al.* (2012a).

Subfamily Giraffinae Zittel, 1893

4.1.3 Genus *GIRAFFA* Brisson, 1756

Type species

Giraffa giraffe Brisson, 1756

Generic diagnosis

Members of this genus are medium sized with much elongated neck and limbs. Basicranial and basipalatal inclined at a small angle. Both sexes have two short ossicones on parieto-frontal and a median naso-frontal protuberance. A pre-lachrymal vacuity is present (Colbert, 1935). Dentition is moderately brachyodont. Premolars are complex and molariform. Buccal enamel coarsely rugose (Harris *et al*., 2010). The enamel forms outgrowths into the fossette from the crescents. Upper teeth are with strong external ribs. Breadth is in excess of length. Lower incisors and canines are robust. Lower molars not elongated, generally rudimentary tubercles but a large one always present in M_1 and generally in M_3 (Matthew, 1929; Colbert, 1935).

Geographic distribution

Giraffa is best known from Pakistan, India, Ethiopia, Kenya, Malawi, Tanzania, South Africa and Uganda (Pilgrim, 1910, 1911 ; Mathew, 1929 ; Hopwood, 1934; Colbert, 1935 ; Dietrich, 1942; Arambourg, 1947; Cooke, 1963; Leakey, 1965; Hendey, 1968, 1969; Mawby, 1970; Taieb *et al.*, 1976; Pickford, 1986, Harris *et al*., 1988 ; Harris, 1991; Schrenk *et al*., 1993; Geraads, 1994; Bromage *et al*., 1995; Ward *et al*., 1999; Basu, 2004; Bhatti *et al*., 2005, 2007b, 2012b; Khan *et al*., 2005, 2010, 2012).

Included species

Giraffa priscilla Matthew, 1929; *Giraffa punjabiensis* Pilgrim, 1910; *Giraffa sivalensis* Falconer and Cautley, 1843; *Giraffa stillei* Dietrich, 1942; *Giraffa pygmaea* Harris, 1976a; *Giraffa jumae* Leakey, 1965; *Giraffa camelopardalis* Linnaeus, 1758.

Giraffa priscilla Matthew, 1929

Lectotype

GSI B511, a left upper third molar.

Type locality

Chinji, Lower Siwaliks, Punjab, Pakistan (Matthew, 1929).

Stratigraphic range

Lower Siwaliks (Matthew, 1929; Colbert, 1935; Basu, 2004; Bhatti, 2005; Khan *et al*., 2012).

Specific diagnosis

Teeth are broad crowned and more brachyodont as compared to *Giraffokeryx*. Anterior rib and metastyle are very strong; in M_3 the more oblique-set inner crescents, broad third lobe with strong accessory basal cusp in front of it, as well as shorter crown (Matthew, 1929).

New material (in parenthesis the inventory number and the locality name are given):

Upper dentition: rP^{2s} (GCUPC 1164/13, Parrhewala; GCUPC 1155/09, Phadial), rP^4 (GCUPC 1147/09, Parrhewala; GCUPC 1176/13, Chinji Rest House), rM^{1s} (GCUPC 1174/09, Dial; GCUPC 1157/12, Bhelomar), lM^{2s} (GCUPC 1142/09, Ratial; GCUPC 1138/09, Parrhewala; GCUPC 1159/12, Dhulian; GCUPC 724/12, Dial; GCUPC 1154/12, Lava; GCUPC 1189/12, Ghungrilla), rM^{2s} (PUPC 68/13, Parrhewala; GCUPC 1139/12, Dial; GCUPC 730/09, Dhulian; GCUPC 906/07, Lava; GCUPC 1186/12, Dhok Bun Amir Khatoon), lM^3(GCUPC 491/02, Chinji Rest House; GCUPC 1121/12, Phadial; GCUPC 490/02, Wasnal).

Lower dentition: lI_3 (GCUPC 1151/12, Dhok Bun Amir Khatoon), lM_2 (GCUPC 673/09, Ratial), rM_2 (GCUPC 1168/12, Phadial), lM_3 (GCUPC 729/05, Wasnal).

Description

Upper dentition

P^2

The teeth are excellently preserved and moderately worn [Figure 4.17 (1, 2)]. The dentine is exposed all over the crown surface. These are quadrangular in appearance. The protocone is moderately worn and its dentine is exposed. It is contiguous with the metaconule posteriorly. The metaconule and protocone are not differentiated due to wearing. The metaconule is connected with metacone by cingular ridges. The paracone is present antero-labially. The preparacrista is shorter than postparacrista. The metacone is pushed outward posteriorly to form pillar like structure called metastyle.

P^4

The premolars are half moon like in shape [Figure 4.17 (3)]. The enamel layer is rugose and somewhat shiny. The median rib is placed labio-medially. The parastyle and metastyle are well developed.

M¹

The upper first molars are well preserved and broad crowned. A thick layer of cingulum is present antero-lingually [Figure 4.17 (4)]. The protocone is V-shaped and the postprotocrista is longer than the preprotocrista. The metaconule is present posterior to the protocone. The premetaconule crista is longer than postmetaconule crista. It appears to be adjoining with protocone at its anterior end. It is supported by a thick layer of cingulum posteriorly.

The paracone is contiguous with metacone through a narrow channel at the posterior side. The paracone extends forward and folds backward anteriorly to produce a very small parastyle. The meta- and mesostyles are incipiently developed. The anterior fossette is present which is V-shaped and quite deep, filled with thin layer of cement. The posterior fossette is also V-shaped, filled by a thick layer of cement. The transverse valley is open lingually. The longitudinal valley is linear antero-posteriorly.

M²

The teeth are broad crowned [Figures 4.17(5, 6), 4.18(1-7)]. A pressure mark is present antero-posteriorly, which indicates that these are the second molars. The lingual cingulum is quite thick and it forms a shelf like structure which is highly corrugated and shiny while the labial cingulum present on the paracone and metacone are incipiently developed in some specimens while it is conspicuous in majority of molars. The preprotocrista and postprotocrista are almost equal in size. It is contiguous with paracone anteriorly by thick enamel vertical fold.

The metaconule is surrounded by a thick layer of enamel. The enamel lining of the metaconule at the lingual side extends backward and is connected with posterior border of the protocone. The metaconule is supported by cingular ridges. The paracone is present antero-labially. It is perfectly V-shaped and its enamel lining antero-labially directed forward and backward to form a pillar like structure named parastyle. The paracone has a very strong and thick labial rib.

The metacone is higher than the paracone. The premetacrista is longer than the postmetacrista. The meta- and mesostyles running at the base of teeth are quite broad and strong. The median ribs are quite thick and pillar like structure present in the middle of the proto- and metacones. The anterior and posterior fossettes are V-shaped and quite shallow, surrounded by thick layer of enamel border. The transverse valley is linear and shallow. The longitudinal valley is wavy and extends antero-posteriorly.

M^3

The molars are excellently preserved, broad crowned, moderately worn and square in outline [Figures 4.18 (8), 4.19 (1-2)]. The third molars are the version of the second molars except the metastyle which is comparatively heavy.

Lower dentition

I_3

The left lower incisor is in middle wear and spade shape [Figure 4.19(3)]. Lingually, the enamel is rough at outer side perhaps due to weathering but crenulated at inner side. It has large and wide cutting furrows at distal edge, which is divided into major and minor lobes. The anterior lobe is narrow while central and posterior are wide. The tooth is laterally compressed showing broad pressure marks caused by the adjacent teeth. The anterolabial side of the tooth is simple, convex and oriented backwardly. The enamel boarder is pinched antero-posteriorly and shows a pressure mark at the base which indicates that it is a last incisor. The lingual side of tooth is also thick, shiny, corrugated and almost simple. The labial side of the tooth is covered by a thin layer of cement.

M_2

These are rectangular in outline, nicely preserved and moderately worn teeth [Figure 4.19 (4-5)]. A well-developed pressure mark is present antero-posteriorly. The major conids are not in straight line. The preprotocristid is longer than the postprotocristid. The both cristids of the hypoconid are contiguous with the protoconid and the entoconid antero-posteriorly. The enamel lining of the metaconid is inclined posteriorly. It is backwardly directed to form a vertical pillar like mesostylid. The metaconid is folded at lingual middle side to form a median rib. The metaconid extends anteriorly and entoconid posteriorly and outwardly to form a thick pillar like metastylid. The entoconid is also supported by a thick median rib.

A quite deep anterior fossette is present between the proto- and metaconids. The posterior fossette is shallow between the hypo- and entoconids. The longitudinal valley is sagittal between the antero-posterior cuspids. The transverse valley is closed by metastylid at lingual side but open at labial side. The ectostylid is present between the proto-hypoconids.

M_3

It is a rectangular shaped molar with well developed hypoconulid [Figure 4.19(6)]. The enamel is heavy and crenulated all around the crown. All the four principal cuspids are well differentiated. The protoconid is somewhat pushed outwardly. The metaconid lingual enamel border is quite thick and shiny. The prematacristid and postmetacristid are almost equal in size. The enamel surface of premetacristid is folded anteriorly forming a thick pillar like structure, the mesostylid, which is supported by cingular ridges. The median rib of the metaconid is quite thick and rugose, supporting the crown surface.

The entoconid is invered V-shape structure and slightly worn at the apices. The preentocristid is shorter as compared to postentocristid. The enamel lining of postentocristid is pushed posteriorly and backwardly to form a quite thin entostylid. The enamel lining of preentocristid extends anteriorly and postmetacristid posteriorly and outwardly to form a very strong and thick metastylid. The median rib of entostylid is quite thick and corrugated. It is narrow distally and quite broad proximally. The hypoconulid is present posteriorly with a fossette. It is quite robust, moderately worn and not in a straight line. The hypoconulid is supported by a stylid.

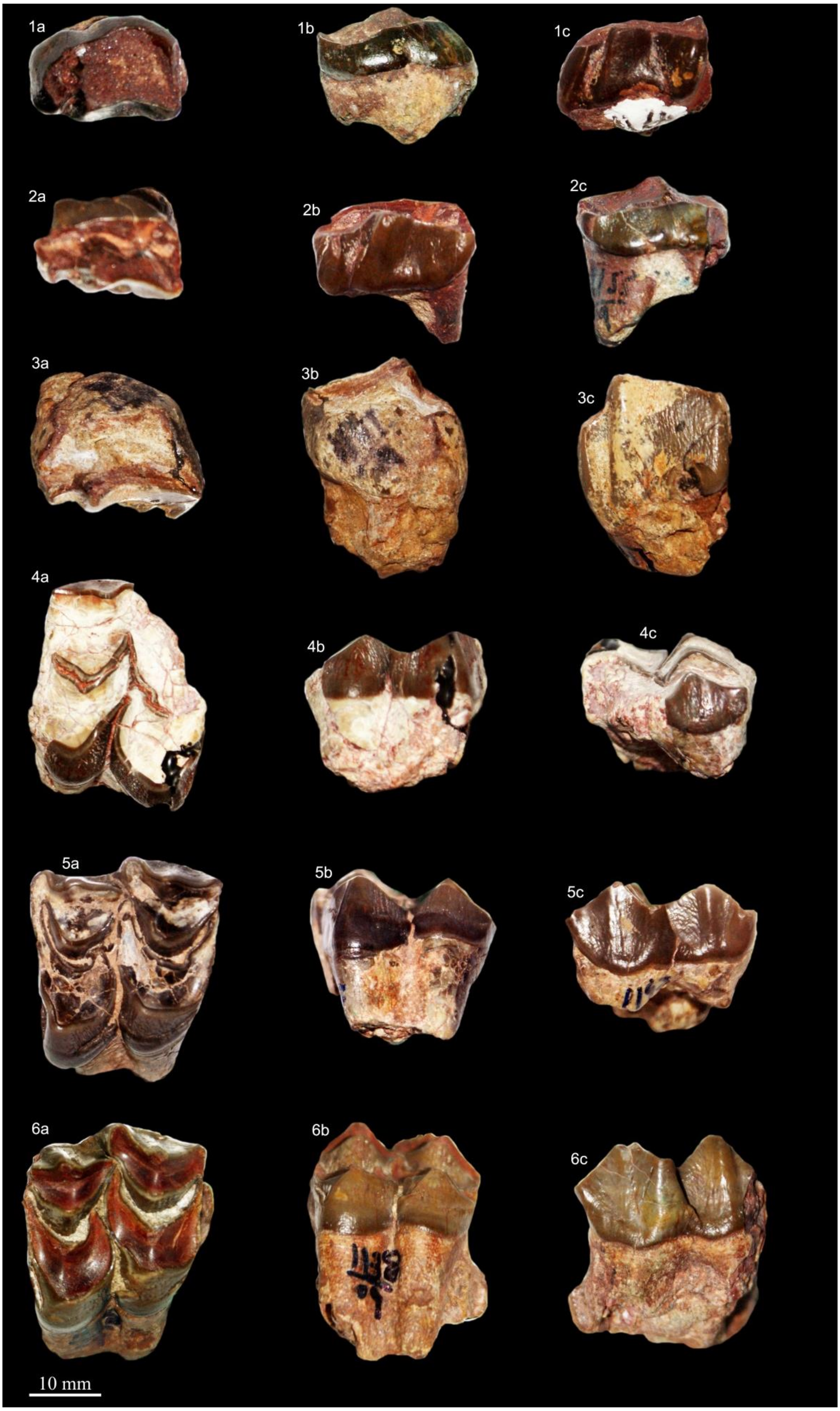


Figure 4.17: *Giraffa priscilla*. 1. GCUPC 1164/13, rP^2. 2. GCUPC 1155/09, rP^2. 3. GCUPC 1147/09, rP^4. 4. GCUPC 1174/09, rM^1. 5. GCUPC 1142/09, lM^2. 6. GCUPC 1138/09, lM^2. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

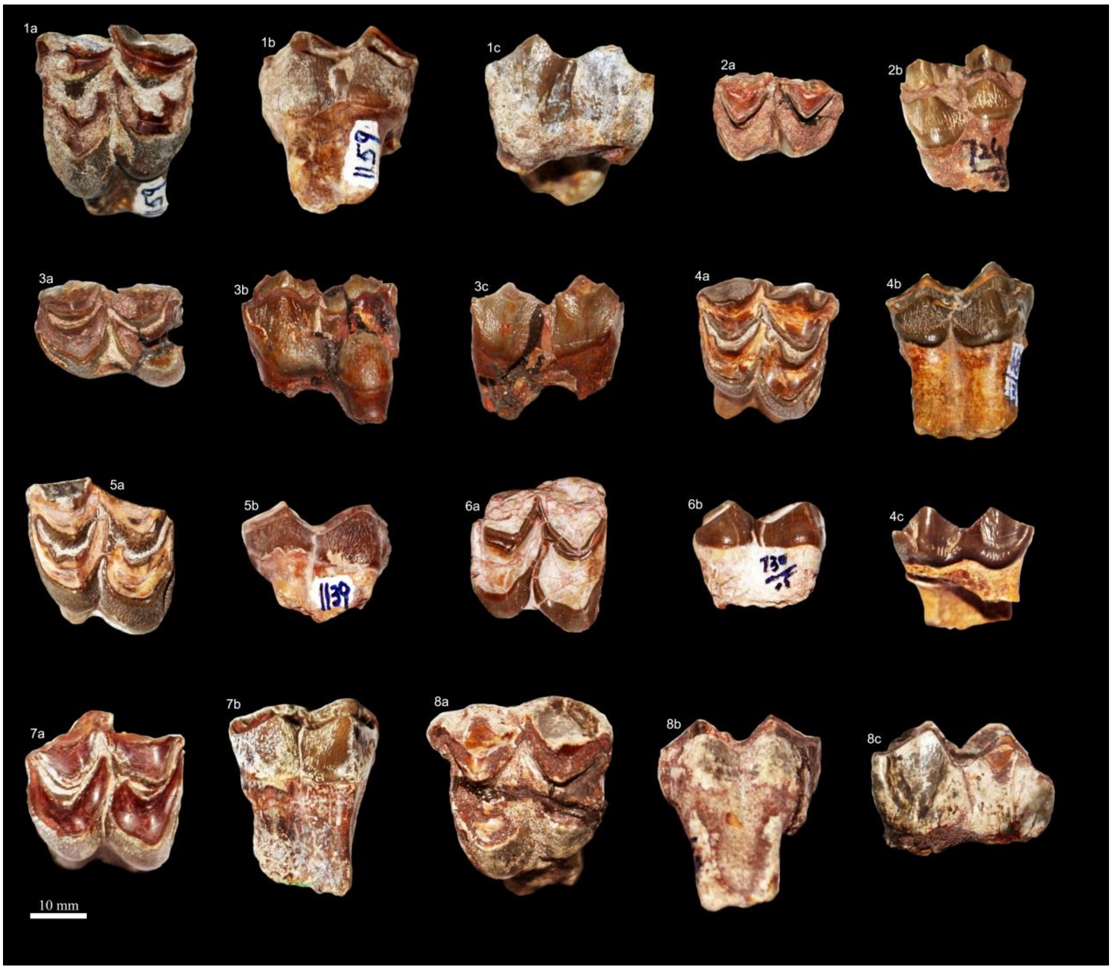


Figure 4.18: *Giraffa priscilla*. 1. GCUPC 1159/12, lM^2. 2. GCUPC 724/12, lM^2 3. GCUPC 1154/12, lM^2. 4. PUPC 68/13 rM^2. 5. GCUPC 1139/12, rM^2. 6. GCUPC 730/09, rM^2. 7. GCUPC 906/07, rM^2. 8. GCUPC 491/02, lM^3. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm).

Figure 4.19: *Giraffa priscilla*. 1. GCUPC 1121/12, lM^3. 2. GCUPC 490/02, lM^3. 3. GCUPC 1151/12, lI_3. 4. GCUPC 673/09, lM_2. 5. GCUPC 1168/12, rM_2. 6. GCUPC 729/05, lM_3. a, occlusal view; b, lingual view; c, labial view (Scale bar 10 mm total).

Table 4.3: Comparative dental measurements of the cheek teeth of the Siwalik *Giraffa priscilla* in mm (millimeters) *the studied specimens. Referred data are taken from Pilgrim (1911), Matthew (1929), Colbert (1935), Bhatti (2005), Bhatti *et al*. (2012b) and Khan *et al*. (2012).

Taxa	Number	Nature	Length (mm)	Width (mm)	W/L
G. priscilla	GCUPC 1164/13*	P^2	21.7	14.5	0.67
	GCUPC 1155/09*	P^2	22.2	14.9	0.67
	GCUPC 1147/09*	P^4	20.3	22.5	1.11
	GCUPC 1176/13*	P^4	21.0	22.0	1.04
	GCUPC 1174/09*	M^1	24.0	24.0	1.00
	GCUPC 1157/12*	M^1	26.0	26.0	1.00
	GCUPC 1142/09*	M^2	25.6	28.9	1.13
	GCUPC 1138/09*	M^2	25.2	28.6	1.13
	GCUPC 1159/12*	M^2	28.6	29.0	1.01
	GCUPC 724/12*	M^2	25.0	28.1	1.12
	GCUPC 1154/12*	M^2	26.4	29.6	1.12
	GCUPC 1189/12*	M^2	26.3	29.2	1.11
	PUPC 68/13*	M^2	25.0	27.5	1.10
	GCUPC 1139/12*	M^2	25.9	28.7	1.11
	GCUPC 730/09*	M^2	26.2	29.1	1.11
	GCUPC 906/07*	M^2	26.0	28.8	1.11
	GCUPC 1186/12*	M^2	25.2	28.1	1.12
	GCUPC 491/02*	M^3	28.8	30.1	1.05
	GCUPC 1121/12*	M^3	28.5	29.1	1.02
	GCUPC 490/02*	M^3	31.2	31.9	1.02
	GCUPC 1151/12*	I_3	13.6	6.7	0.49
	GCUPC 673/09*	M_2	26.8	16.6	0.62
	GCUPC 1168/12*	M_2	26.0	15.8	0.61
	GCUPC 729/05*	M_3	41.2	22.5	0.55
	PUPC 02/99	P^4	19.5	21.0	1.08
		M^1	24.0	24.0	1.00
		M^2	25.0	28.0	1.12

Table 4.3 (continued)

	PUPC 07/131	M^1	25.0	25.0	1.00
	PUPC 07/89	M^1	27.0	27.0	1.00
	PUPC 02/9	M_3	40.0	17.0	0.43
G. punjabiensis	GSI	P^4	20.5	26.6	1.30
		M^1	28.2	30.8	1.09
		M^2	31.5	34.5	1.10
		M^3	32.0	31.5	0.98
	GSI K 13/349	P^4	22.0	20.0	0.91
		M^1	30.0	24.0	0.80
		M^2	32.0	24.0	0.75
		M^3	30.0	22.0	0.73
	GSI B 182	M^3	29.0	31.0	1.06
	GSI K 13/348	M^3	31.0	33.0	1.06
	PUPC 95/23	P^4	20.0	23.0	1.15
		M^1	31.0	27.0	0.87
		M^2	34.0	28.0	0.82
		M^3	31.0	23.0	0.74
	PUPC 86/84	M^1	21.0	28.0	1.33
		M^2	34.0	27.0	0.79
		M^3	31.0	24.0	0.77
	GSI	M_2	28.3	32.2	1.14
		M_3	43	23.2	0.54
	AMNH 19318	M_2	26.0	25.0	0.96
G. sivalensis	GSI	M^2	33.0	37.0	1.12
		M^3	30.4	35.5	1.17
	PUPC 69/123	P^4	18.0	22.5	1.25
	PUPC 68/317	M^3	27.0	29.0	1.07
	PUPC 67/484	M^3	28.0	28.0	1.00
	GSI	M_3	43.5	25.2	0.58

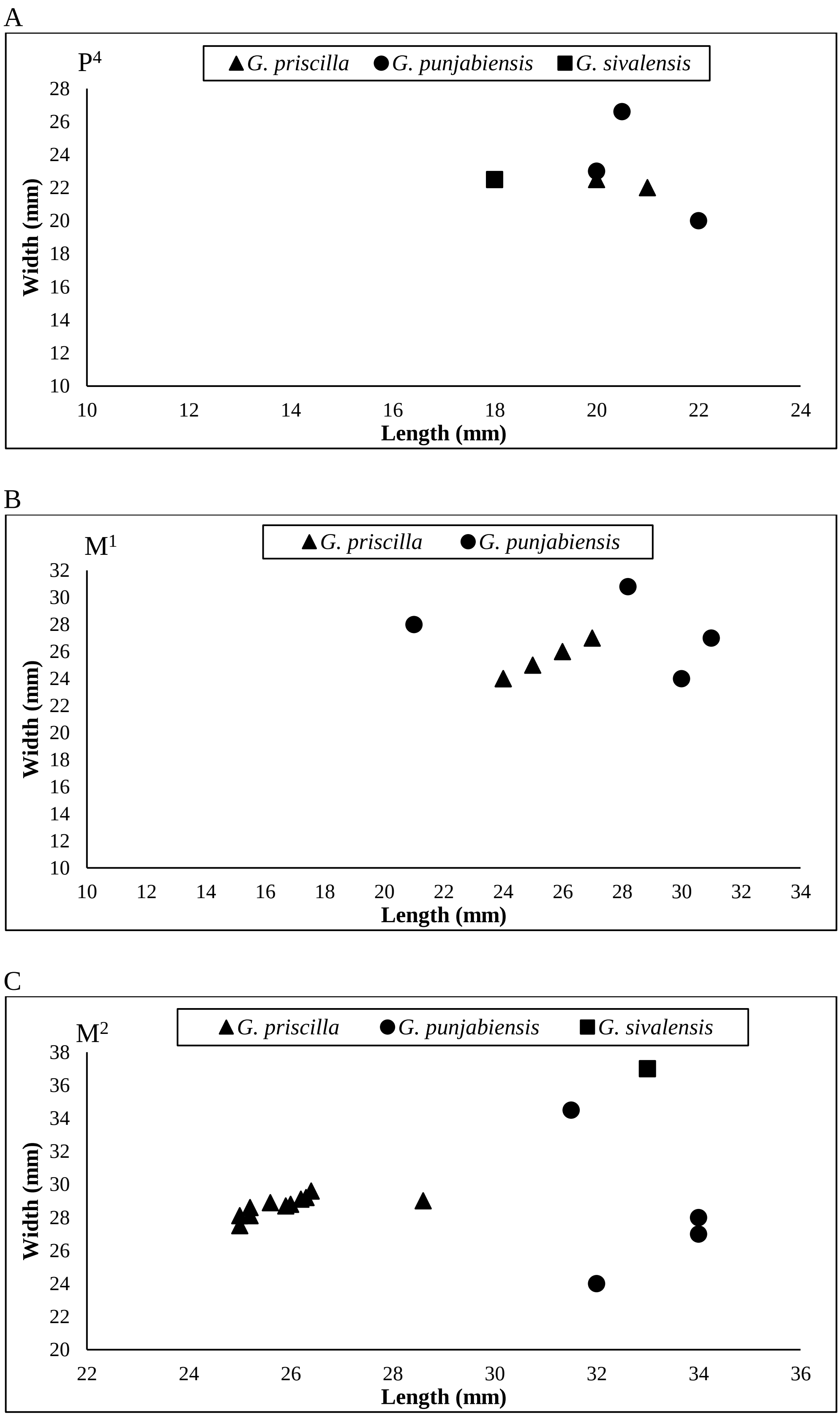


Figure 4.20: Scatter diagram showing dental proportions of the Siwalik *Giraffa* species; A, upper fourth premolars; B, upper first molars; c, upper second molars. Referred data are taken from Pilgrim (1911), Matthew (1929), Colbert (1935), Bhatti (2005), Bhatti *et al*. (2012b) and Khan *et al*. (2012).

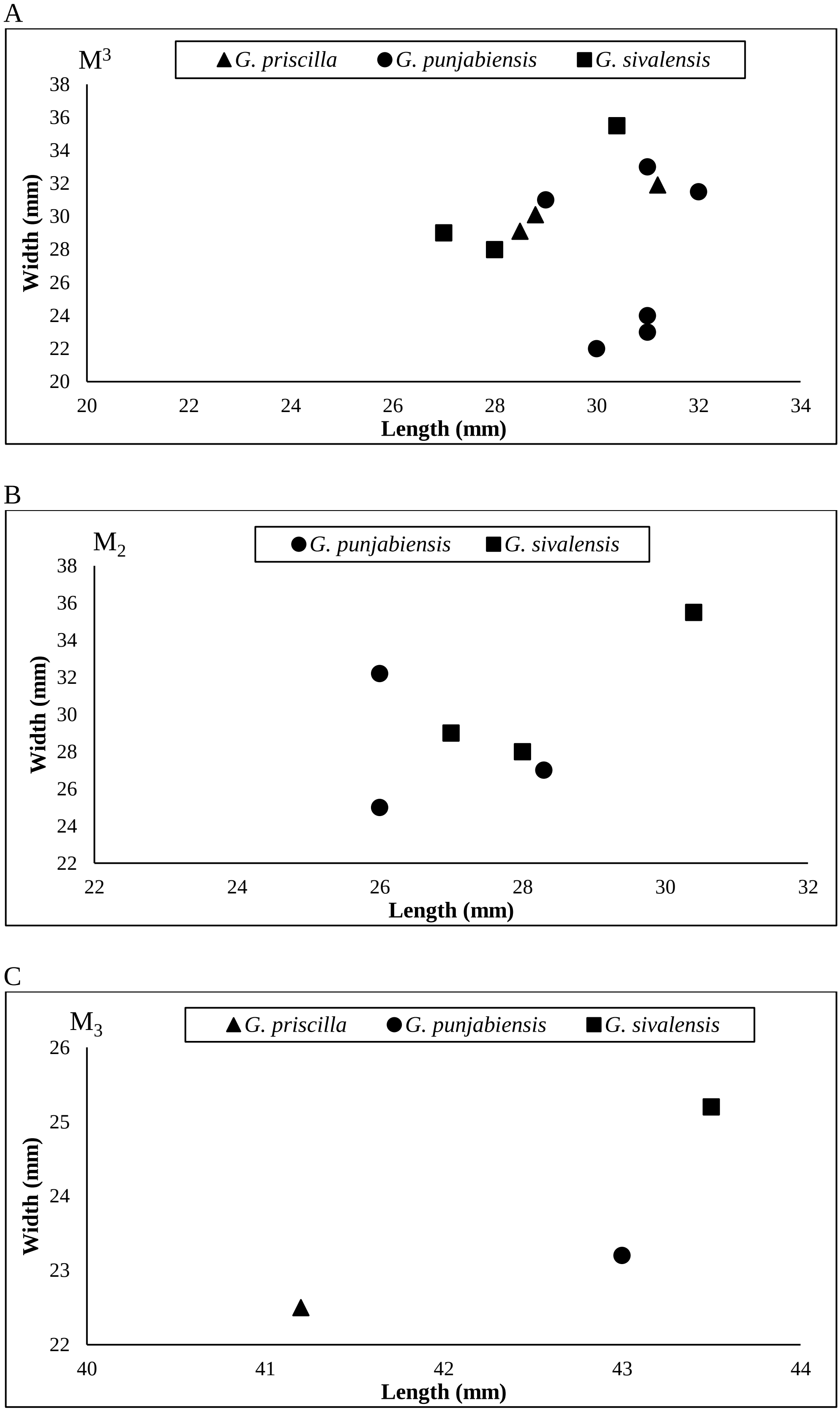


Figure 4.21: Scatter diagram showing dental proportions of the Siwalik *Giraffa* species; A, upper third molars; B, lower second molars; C, lower third molars. Referred data are taken from Pilgrim (1911), Matthew (1929), Colbert (1935), Bhatti (2005), Bhatti *et al*. (2012b) and Khan *et al*. (2012).

Chapter 5

DISCUSSION

The material under study comprises tetracuspid multituberculated teeth (premolars and molars), so it can be safely placed in the class Mammalia (Pilgrim, 1910; Colbert, 1935; Romer, 1974). Since the structure of the specimens appears to be herbivorous, it can be attributed to either order Artiodactyla or Perissodactyla. The teeth are crescent in out-line, it can be included in the suborder Ruminantia (Zittel, 1925). The specimens are rugose and the rugosity is prominent in the family Giraffidae. Furthermore, the specimens have typical giraffid characteristics in representing rugose enamel, obliquity of labial cusps, brachydonty to moderately hypsodonty, posterior region of the P_4 separated from the central and anterior regions, central lingual cuspid strongly developed on P_4 and not joined to the central labial cuspid (Pilgrim, 1911; Matthew, 1929; Colbert, 1935; Churcher, 1978; Bhatti, 2005; Harris *et al*., 2010).

In the Siwaliks, both large and small genera are present. The specimens under study are smaller in size so cannot be compared with the maxilla and mandibles of the large subfamily Sivatheriinae (*Helladotherium, Hydaspitherium, Vishnutherium, Sivatherium* and *Bramatherium*) (Khan *et al.*, 2010; Bhatti *et al.*, 2012a, b). They can be referred to the small subfamilies Progiraffinae (*Progiraffa*), Giraffinae (*Giraffa*) and Giraffokerycinae (*Giraffokeryx*).

The specimens of the genus *Progiraffa* (Figures 4.1-4.3) are characterized in having united postprotocrista and premetaconule crista by an enamel complex, well-developed cingulum on preprotocrista, bifurcated postmetaconule crista, rugose enamel, prominent styles, strong anterior median ribs and flat posterior median ribs, and convex meta-entoconid lingually. These unique characters resemble with the dental features of the species *P. exigua* (Pilgrim, 1911; Barry *et al*., 2005).

Furthermore, the material has strong parastyles, mesostyles and anterior median ribs. The metaconule of upper molars is bifurcated posteriorly (Figures 4.1, 4.2). The cingulum is well developed anteriorly and incipiently develops or absent posteriorly. In lower dentition, the enamel is crenulated. The premolars are long and low crowned (Figure 4.3). In molars, the median ribs are weak, metastylid is large, preprotocristids and premetacristids unites to each other. In M_3, half-moon shape hypoconulid is present. These features resemble to the specimens described by Pilgrim (1911) and Barry *et al*. (2005). Resultantly, the specimens are referred to *Progiraffa exigua* and can be compared with the specimens housed in the Indian Museum, Kolkata, the Geological Survey of Pakistan-Sind Collection (GSP-S), the Geological Survey of Pakistan-Harvard University Project (GSP-Y) and the Geological Survey of Pakistan-Howard University Project (GSP-H) (Table 4.1, Figure 4.4-4.6).

Progiraffa has ossicones which show that it belongs to Family Giraffidae. Its basicranium have small basilar tubercles and an oval auditory bulla, which is well separated from basioccipital. The skull and dentition of *Progiraffa* is different from primitive giraffoids such as *Propalaeoryx, climacoceras, Canthumerys, Prolibytherium* and *Nyanzameryx* by presence of more prominent and well separated metastylid (Vasishat *et al.*, 1979). In *Propalaeoryx,* the protocone is more anterior in P^3. In *climacoceras* upper molars are narrow. In *Canthumeryx*, lingual basal structure is much developed. In *Nyanzameryx* and *Prolibytherium,* lingual cusps of lower molars are compressed and lingual wall of hypoconulid is incomplete in M^3 (Barry *et al.*, 2005).

In 1908, Pilgrim referred a single specimen to the genus *Progiraffa.* Latter on, Pilgrim (1911) described two species of this genus *P. exigua and P. sivalensis*. Barry *et al.* (2005) gave a description of *Progiraffa exigua* from the Early Miocene localities of Pakistan. This species is reported first time from the Chinji Formation of the Lower Siwaliks. The Siwalik *Progiraffa* may be congeneric with *Prolibytherium* or *Injanatherium* of Eurasia (Solounias, 2007).

In the species *Giraffokeryx punjabiensis* (Figure 4.7-4.12), the teeth are selenodont and the enamel is rugose therefore these are referred to the family Giraffidae (Pilgrim, 1911; Khan *et al*., 2010). The premolars and molars are small in size, so they can be placed into subfamilies Progiraffinae, Giraffokerycinae and Giraffinae. The specimens differ from Progiraffinae in having relatively higher degree of hypsdonty. The sample differs from Giraffinae in having less developed external folds (De Bonis *et al.*, 1997; Solounias, 2007).

The specimens are represented by the following characteristics: brachyodont dentition with rugose enamel, weak styles/stylids and entostyles/ectostylids, and weak median ribs. The P^{3s} are with crescentic fossettes (Figure 4.7). These premolars are longer than the P^{4s} (Table 4.2). In the upper molars, the parastyles and mesostyles are well differentiated and the metastyles are weakly developed. The median ribs are incipiently developed and the entostyles are absent (Figures 4.7-4.9). These features associate the sample to the subfamily Giraffokerycinae and the genera *Giraffokeryx* (Pilgrim, 1911; Matthew, 1929; Colbert, 1935; Solounias, 2007; Harris *et al*., 2010; Bhatti *et al.*, 2012a). The lower second and third premolars of *G. punjabiensis* are more rectangular in shape as compared to other genera of family Giraffidae.

The lower fourth premolar of *Giraffokeryx* resembles that of *Palaeotragus tungurensis* (*P. primaevis*) (Hamilton, 1978). The P_4 of *Giraffokeryx anatoliensis* is different from *Giraffokeryx punjabiensis* in having bifurcated protoconid (Geraads and Aslan, 2003). The lower first and second molars represent less prominent stylids, median ribs and ectostylids (Figures 4.10, 4.11, 4.12). These characters are present in lower molars of *G. punjabiensis* (Pilgrim, 1910; Colbert, 1935; Gentry, 1990; Bhatti *et al*., 2007a, 2012a). In M_3, ectostylid is tiny, hypoconid is less twisted and metastylid is less developed (De Bonis *et al*., 1997).

On the basis of these similarities, measurements and W/L index (Table 4.2), all the premolar and molars refer to *G. punjabiensis* and can be compared with the specimens housed in the American Museum of Natural History New York, Indian Museum Kolkata, India and the Punjab University Palaeontological Collection Stored in Zoology Department, University of the Punjab, Lahore, Pakistan (Table 4.2, Figure 4.13-4.16) (Pilgrim, 1910, 1911; Matthew, 1929; Colbert, 1935; Bhatti *et al*., 2012a).

According to recent revision by Solounias (2007), the family Giraffidae comprises seven subfamilies, four of which are reported from the Siwaliks: Progiraffinae, Giraffokerycinae, Giraffinae and Sivatheriinae. Progiraffinae comprises the genus *Progiraffa.* Giraffinae includes the genus *Giraffa* and the subfamily Sivatheriinae represented by *Sivatherium, Bramatherium, Helladotherium, Hydaspitherium* and *Vishnutherium*. The genus *Giraffokeryx* is placed in the subfamily Giraffokerycinae.

The genus *Giraffokeryx* may evolve from *Progiraffa* (Pilgrim, 1911) gaining crown height in cheek teeth, small basal pillars and less prominent metastylids (Gentry, 1990). *Giraffokeryx punjabiensis* can be distinguished by brachydont to subhypsodont teeth with some degree of variation. Progiraffinae (*Progiraffa*) and Giraffinae (*Giraffa priscilla*) differ from Giraffokerycinae in having well developed stylids and median ribs.

The specimens under study (Figure 4.17-4.19) are brachydont and small in size having thick enamel sculpture, so they resemble best with the Lower Siwalik genera *Giraffokeryx* or *Giraffa* (Colbert, 1935; Bhatti, 2005; Khan *et al.,* 2010). However, these two differ greatly in their dental morphological characteristics.

In *Giraffokeryx,* major cusps and conids are in a straight line (Pilgrim, 1911; Bhatti, 2005), styles are weakly developed and stylids are absent (Pilgrim, 1910; Colbert, 1935; Bhatti, 2005; Bhatti *et al*., 2012a), median ribs are weak (Matthew, 1929; Colbert, 1935), spur is present in anterior fossette (Bhatti, 2005) and crown is narrow as compared to *Giraffa* (Bhatti *et al*., 2012a). In *Giraffa,* major cusps and conids are not in a straight line (Pilgrim, 1911; Bhatti, 2005), styles are strong and pillar like and stylids can be clearly observed (Colbert, 1935; Bhatti *et al*., 2012b), median ribs are prominent (Matthew, 1929; Colbert, 1935), spur is absent in anterior fossette (Bhatti, 2005) and crown is comparatively broad (Bhatti *et al*., 2012b).

Regarding size and morphological dental features, the specimens are very close to genus *Giraffa* (Table 4.3, Figures 4.17- 4.19). Three species of this genus are present in the Siwaliks of Pakistan *Giraffa priscilla, Giraffa punjabiensis,* and *Giraffa sivalensis. Giraffa sivalensis* is a large species present in the Upper Siwaliks of Pakistan. The posterior half of tooth is much reduced as compared to other species of this genus. The metastyle is not prominent in this species (Colbert, 1935; Bhatti, 2005). *Giraffa punjabiensis* is recorded from Middle Siwaliks of Pakistan. It is distinguished from other species by having less reduced posterior half of tooth and weak metastyle. *Giraffa punjabiensis* and *G. sivalensis* are the Late Miocene and Pleistocene species of the Siwaliks respectively.

Giraffa priscilla is only reported from the Lower Siwaliks of Pakistan. It differs from other two species of *Giraffa* by having less reduced posterior half and strong pillar like metastyle. The studied specimens are characterized in having broad crown, obliquely present cusps/conids, strong styles/stylids and well developed median ribs. The posterior half of the tooth is also reduced as compared to *Giraffokeryx.* On the basis of these similarities i.e. morphological features, measurements and W/L index (Table 4.3), all the premolar and molars refer to *Giraffa priscilla* and can be compared (Figure 4.20-4.21) with the specimens discussed by Pilgrim (1911), Matthew (1929), Colbert (1935), Bhatti (2005) and Bhatti *et al*. (2012b). This species was identified by Matthew (1929) and is known only from the

Middle Micocene localities of the Lower Siwaliks (Colbert, 1935; Basu, 2004; Bhatti, 2005).

5.1 Faunal Correlation

The Lower Siwaliks comprises the Middle Miocene fauna. Giraffidae made their first appearance in the Kamlial Formation. This Formation is Middle Miocene in age and can be compared with the Middle Miocene of Dera Bugti, Zinda Pir and Manchar sites in Pakistan (Raza and Meyer, 1984; Johnson *et al*., 1985; Pickford, 1988; Ginsburg *et al*., 2001; Welcomme *et al*., 2001). The Kamlial fauna is younger than Dera Bugti and Zinda Pir but it is equivalent to Manchar (Van Couvering *et al*., 2000). From all these sites, the *Progiraffa* remains have been recovered (Pilgrim, 1910, 1911; Barry *et al*., 2005).

Georgimeryx and *Canthumeryx* were Early to Middle Miocene giraffids of Europe and Africa, equivalent to *Progiraffa* of the Siwaliks. *Georgimeryx* has been recovered from Greece (De Bonis *et al*., 1997). *Canthumeryx* has been recorded from Buluk, Kalodirr, Locherangan, Maboko, Moruorot, Ombo, and Rusinga in Kenya (MacInnes, 1936; Whitworth, 1958; Madden, 1972; Thomas, 1984; Leakey and Walker, 1985; Leakey and Leakey, 1986; Pickford, 1986; Anyonge, 1991), Gebel Zelten in Libya (Hamilton, 1973, 1978), Al-Sarrar in Saudi Arabia (Thomas *et al.*, 1985) and Napak in Uganda (Bishop, 1962, 1967). These outcrops belong to the Early-Middle Miocene.

The Chinji Formation is Middle Miocene in age (Barry *et al*., 2002). *Progiraffa*, *Giraffokeryx punjabiensis* and *Giraffa priscilla* have been recorded from this Formation. *Giraffa priscilla* is endemic to the Chinji Formation of the Siwaliks. It is unknown from outside this region. However a few specimens are mentioned from the Nagri Formation of the Middle Siwaliks by Khan *et al*. (2012). The species has been also recognized from the Indian Middle Miocene locality of Ramnagar (Basu, 2004).

This faunal assemblage can be correlated to the Middle Miocene of the Eurasia. The Chinji fauna shows resemblance to Middle Miocene Fort Ternan, Kenya (Gentry, 1970; Churcher, 1970, 1978; Hamilton, 1978; Shipman *et al*., 1981). Geraads and Aslan (2003) recovered *G. anatoliensis* from Candir, Turkey. This locality is Middle Miocene in age (Kohler, 1987). *Giraffokeryx* also recognized from Prebreza (Yugoslavia) and Nakali (Kenya). All these localities are Middle Miocene in age

(Pavlovic, 1969; Aguirre and Leakey, 1974). Gentry (1990) identified *Giraffokeryx* aff. *punjabiensis* from the Middle Miocene locality of Pasalar (Turkey).

The Chinji faunal elements resemble Middle Miocene fauna of Beni Mellal, Morocco (Heintz, 1976), Tung Gur, Mongalia (Pilgrim, 1934; Li *et al*., 1984) and Al Jadidah (Thomas, 1983; Morales *et al.,* 1987). From these localities *Palaeotragus* and *Injanatherium* has been recovered which are similar to *Giraffokeryx.* The Kamlial and Chinji faunas are different form the Dhok Pathan and Soan formations due to presence of large giraffids i.e. *Bramatherium*, *Sivatherium*, *Hydaspitherium* and *Helladotherium* (Sarwar and Akhtar, 1987; Bhatti *et al*., 2012c; Khan and Akhtar, 2014a).

5.2 Palaeoecology

The documented giraffid species from the Siwalik Middle Miocene are associated with *Miotragocerus*, *Tragoportax*, *Helicoportax*, *Elachistoceras*, *Gazella*, *Microbunodon*, *Merycopotamus*, *Listriodon*, *Conohyus*, *Dorcatherium*, *Dorcabune*, *Gaindatherium* and *Hespanotherium*. Nevertheless, the bovids are recorded abundantly from the Siwalik Middle Miocene (Lydekker, 1876, 1880, 1883a, b, 1884; Pilgrim, 1910, 1915, 1937, 1939; Colbert, 1933, 1935; Raza, 1983; Thomas, 1984; Akhtar, 1992; Badgley *et al.*, 2008; Khan *et al.*, 2008, 2009, 2010; Khan and Akhtar, 2011, 2013).

The Lower Siwalik giraffids indicate a mixture of several types of habitats, ranging wet lands with dense forested pockets to woodlands. The medium sized gazelle community is also related to widespread open or bushy land mass at no great distance (Solounias *et al.*, 1994). The abundance of bovids together with rhinocerotids, giraffids, listriodon and tragulids are conclusive evidence of a wet and probably forested landscape. *Miotragocerus* and *Tragoportax* are more often associated with the giraffids, but most of the sites are Middle-Late Miocene in age, and are located in the Potwar Plateau of northern Pakistan (Khan *et al*., 2012; Khan and Akhtar, 2013), implying that they probably exploited different feeding resources within a same environment.

The presence of the forest inhabitants (*Progiraffa*, *Giraffokeryx*, *Giraffa*, *Hispanotherium*, *Deinotherium*, *Gaindatherium*, *Brachypotherium* and *Listriodon*) with *Dorcatherium* reflects rather a humid climate (Kohler, 1993; Rossner, 2010) with woodland to savannah environment at or near Lava during the Middle Miocene. The presence of suiformes with the giraffids in the Pakistani Chinji Formation indicates the occurrence of parkland-like landscape (Farooq *et al.,* 2008; Khan *et al.,* 2008, 2012; Khan and Akhtar, 2013).

Microbunodon silistrensis recorded from the Siwalik Middle Miocene showed that it was more likely to be a small, terrestrial and cursorial species (Cabard, 1976; Lihoreau, 2003). *Merycopotamus* fossils exhibit some morphological evidence for adaptation to life in water and shows strong morphological affinities with the aquatic environment. So the patterns before 11 million years ago thus reflect the development of regionally diversified climate systems which is comparatively different from the present one. It may be characterized that climate of the Middle Miocene as warm and humid with a strong monsoon circulation (Barry *et al*., 2002).

The bovids, tragulids, giraffids, anthracotheriodes and pigs suggest moist, forested habitat. As a whole, one can presume that the vertebrate fauna of the Siwalik Middle Miocene represents a mixture of several types of habitats, brought together by the fluvial transport. This faunal association suggests wet lands with dense forested pockets, where the animals could hide in vegetation from predators.

The palaeosols present in the Siwaliks are also a very good source of palaeoecological information. (Johnson, 1977; Visser and Johnson, 1978; Johnson *et al.,* 1982a; Tandon and Narayan, 1981; Behrensmeyer and Tauxe, 1982; Retallack, 1985, 1991). The presence of calcite in palaeosols confirms that the Lower Siwaliks consists of moderate rainfall fauna. The feldspars in sand stones indicate that climate was humid at that time (Dickinson and Suczek, 1979). These evidences also show that the Lower Siwalik fauna was wet and humid with increase precipitation.

Based on the recovered faunal elements, it is suggested that the older Lower Siwaliks suggests closed cover (forest and heavy cover) conditions and the younger Lower Siwaliks suggests half closed and half opened woodland ecosystem. Aquatic ecosystems were common occurrence of minor flood plain channels and ponds, besides the existence of major channels. The Chinji Formation localities likely represent more uniformly forested conditions with a continuous canopy. The available specimens from the Siwalik Middle Miocene were arguably from forest-adapted taxa, or at the very least heavy cover specialists. Thus, the Lower Siwaliks appear to suggest a mosaic forested-wetland palaeoenvironment.

5.3 Biostratigraphy

The mammalian species identified from the Siwalik Middle Miocene on the basis of the published and unpublished work (Lydekker, 1876, 1880, 1883a, b, 1884;

Pilgrim, 1910, 1915, 1937, 1939; Colbert, 1933, 1935; Raza, 1983; Thomas, 1984; Akhtar, 1992; Badgley *et al.*, 2008; Khan *et al.*, 2008, 2009, 2010, 2011, 2012; Khan and Akhtar, 2011, 2013) are as follows:

Creodonta	Hyaenodontidae: *Dissopsalis carnifex*, *Dissopsalis rubber*.
Carnivora	Canidae: *Amphicyon palaeindicus*, *A. Pithecohilus*, *Vishnucyon chinjiensis*; Procyonidae: *Sivanasua palaeindica*; Mustelidae: *Martes lydekkeri*; Viverridae: *Viverra chinjiensis*.
Proboscidea	Deinotheriidae: *Deinotherium pentapotamiae*, *D. indicum*; Gomphotheriidae: *Gomphotherium angustidens*, *G. macrognathus*, *G. chinjiensis; Tetralophodon falconeri*.
Perissodactyla	Chalicotheriidae: *Nestoritherium (?) sindiense, Macrotherium salinum;* Rhinocerotidae: *Gaindatherium browni, Aceratherium perimense, A. blanfordi, Chilotherium intermedium, Brachypotherium fatehjangense.*
Artiodactyla	Tayassuidae: *Pecarichoerus orientalis*; Suidae: *Palaeochoerus perimensis*, *Conohyus sindiense*, *C. chinjiensis*, *Listriodon pentapotamiae*; Anthracotheriidae: *Anthracotherium punjabiense, Hemimeryx blanfordi*, *H. pusillus*; Tragulidae: *Dorcabune anthracotherioides*, *Dorcatherium majus*, *D. minus*, *D. nagrii*, *D. minimus*; Giraffidae: *Giraffokeryx punjabiensis*, *Giraffa priscilla*; Bovidae: *Miotragocerus gluten*, *Kubanotragus sokolovi*, *Sivoreas eremita*, *Sivaceros gradiens*, *Caprotragoides potwaricus*, *Elachistoceras khauristanensis*, *Helicoportax tragelaphoides*, *H. praecox*, *Eotragus* sp., *Gazella* sp., *Palaeohypsodontus* sp.
Primates	*Sivapithecus sivalensis*, *S. indicus*, *Ramapithecus punjabicus*, *Dryopithecus punjabicus*, *D. pilgrimi*, *D. chinjiensis*.
Rodentia	*Rhizomyoides punjabiensis.*

The age of the above mentioned species is clearly of Middle Miocene, because many species are part of the Siwalik mammalian fauna, likely to be the end representatives of the Middle Miocene (Khan *et al*., 2010, 2011, 2012). *Progiraffa* agrees better with the Middle Miocene mammalian fauna than with those of the Late Miocene or later (Barry *et al*., 2005). *Giraffa priscilla* and *Giraffokeryx punjabiensis* are recorded from 14.2 to 10 Ma (Matthew, 1929; Colbert, 1935; Khan *et al*., 2012). A few specimens of *Giraffokeryx* and *Giraffa* have been recorded from the base of the

Nagri Formation and the species completely disappeared around 10 Ma from the Subcontinent (Khan *et al.,* 2012). The Siwalik dinotheriids, chalicotheriids, canids, listriodons, tragulids, and the early giraffids are also present in the Middle Miocne of Graeco-Iranian province as well as in Eurasia (Matthew, 1929; Colbert, 1935; Solounias, 2007).

Based on the fossil record, it seems that the early giraffids disappear after the Middle Miocene. Therfore it is recommended that the stratigraphical range of the early Siwalik giraffids is of Early to Middle Miocene. *Progiraffa* is present in the Lower Siwaliks from 18.3 to 13.2 Ma. *Giraffokeryx punjabiensis* is recorded from the Middle Miocene to Early Late Miocene of the Siwaliks with an estimated age 14.2 to 10 Ma (Colbert, 1935; Bhatti, 2005; Khan *et al*., 2012). *Giraffa priscilla* is present Middle to Early Late Miocene of the Siwaliks (Matthew, 1929; Basu, 2004; Bhatti, 2005; Khan *et al*., 2012).

From the above discussion, it is concluded that the recovered giraffid fossils range between 18.3–11.2 Ma in age and provide evidence for the existence of early giraffid fauna in the Lower Siwaliks of northern Pakistan. *Progiraffa exigua* is recorded from the Kamlial (ca. 18.3–14.2 Ma) and the Lower Chinji formations (ca. 14.2–13.2 Ma) of the Lower Siwaliks.

The new findings of *Progiraffa exigua* from the Lower Chinji Formation of the Siwaliks extend its stratigraphical range from the Kamlial Formation to the Chinji Formation of the Lower Siwaliks. Prior to this study the species was only restricted to the Early Miocene of the Subcontinent. *Giraffokeryx punjabiensis* and *Giraffa priscilla* are known from the Chinji Formation (14.2–11.2 Ma) of the Lower Siwaliks. The presence of *Giraffokeryx punjabiensis* and *Giraffa priscilla* in the Middle Miocene of the Siwaliks shows its widespread distribution in the Subcontinent.

The early Siwalik giraffids can be correlated to the Early-Middle Miocene localities of Eurasia and Africa. The abundance of bovids with the early giraffids in the Chinji Formation indicates mixture of woodland and grassland biomes. The association of the small bovids (*Eotragus, Elachistoceras*) and the tragulids (*Dorcatherium, Dorcabune*) with the Lower Siwalik giraffids indicates more or less closed and humid habitats. The presence of rhinocerotids indicates that the climate was probably not very dry during Middle Miocene in the Siwaliks and there were more rivers and lakes. The early Siwalik giraffids with the bovids, tragulids, anthracotheriodes and rhinocerotids suggest moist, forested habitat. One can presume that the vertebrate fauna of the Lower Siwalik represents a mixture of several types of habitats, ranging wet lands with dense forested pockets to woodlands.

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APPENDIX

Studied Material

Progiraffa exigua

Studied Specimens: Upper dentition: A left maxillary ramus with DP^{2-4}-M^1 (GCUPC 1149/12, Dhok Bun Amir Khatoon), lP^2 (GCUPC 1145/12, Dhok Bun Amir Khatoon), rdP^3 (GCUPC 984/09, Jaba), lM^{1s} (PUPC 12/55, PUPC 88/10, Chinji Rest House), rM^{1s} (GCUPC 1137/09, Jaba; PUPC 84/77, Rakh Wasnal), rM^{2s} (GCUPC 1136/09, Jaba; GCUPC 1177/09, Rakh Wasnal; GCUPC 1180/09 Dhok Bun Amir Khatoon; GCUPC 230/99, Chinji Rest House)

Lower dentition: rP_2 (PUPC 81/91, Ghungrila), lP_3 (PUPC 71/70, Rakh Wasnal), rM_{2-3} (PUPC 66/07, Ghungrila).

Giraffokeryx punjabiensis

Studied Specimens: Upper dentition: lP^{3s} (GCUPC 1141/09, GCUPC 1170/12, Chabbar Sayadan), rP^{3s} (GCUPC 1173/09, Bhelomar; GCUPC 1072/09, Wasnal), lP^4 (GCUPC 707/05, Chinji Rest House), rP^4 (GCUPC 1162/13, Chinji Rest House), a left maxillary ramus with P^4-M^1 (GCUPC 706/05, GCUPC 1162/13, Chinji Rest House), rM^1 (GCUPC 1185/12, Dhok Bun Amir Khatoon), lM^{2s} (GCUPC 1172/09, Bhelomar; GCUPC 1187/12, GCUPC 1188/12, Dhok Bun Amir Khatoon; GCUPC 1353/09, Chinji Rest House), rM^{2s} (GCUPC 1183/12, GCUPC 1184/12, Parrhewala; GCUPC 1167/12, Dhok Bun Amir Khatoon; GCUPC 1144/09, Bhelomar), a left maxillary ramus bearing M^{2-3} (GCUPC 1135/09, Chinji Rest House), rM^3 (GCUPC 1148/12, Dhok Bun Amir Khatoon).

Lower dentition: rP_2–M_1 (GCUPC 1161/12, Dhok Bun Amir Khatoon), rP_{2-3}(GCUPC 1140/12, Bhelomar), rP_3–M_3 (GCUPC 1165/13, Dhok Bun Amir Khatoon) lP_{3s} (GCUPC 1190/12, GCUPC 1171/12, Dhok Bun Amir Khatoon), rP_4 (GCUPC 1150/09, Ghungrilla; GCUPC 1175/13, Chinji Rest House), rM_1 (GCUPC 1152/12, Dhulian), lM_{2s} (GCUPC 1156/12, Ghungrilla; GCUPC 1146/12, Dial), rM_{2s} (GCUPC 1143/12, Phadial; GCUPC 720/05, Lava), lM_{3s} (GCUPC 959/08, Bhelomar; GCUPC 1182/12, Dhulian), rM_3 (GCUPC 1181/12, Lava; GCUPC 419/01, Dial).

Giraffa priscilla

Upper dentition: rP^{2s} (GCUPC 1164/13, Parrhewala; GCUPC 1155/09, Phadial), rP^4 (GCUPC 1147/09, Parrhewala; GCUPC 1176/13, Chinji Rest House),

rM^{1s} (GCUPC 1174/09, Dial; GCUPC 1157/12, Bhelomar), lM^{2s} (GCUPC 1142/09, Ratial; GCUPC 1138/09, Parrhewala; GCUPC 1159/12, Dhulian; GCUPC 724/12, Dial; GCUPC 1154/12, Lava; GCUPC 1189/12, Ghungrilla), rM^{2s} (PUPC 68/13, Parrhewala; GCUPC 1139/12, Dial; GCUPC 730/09, Dhulian; GCUPC 906/07, Lava; GCUPC 1186/12, Dhok Bun Amir Khatoon), lM^{3}(GCUPC 491/02, Chinji Rest House; GCUPC 1121/12, Phadial; GCUPC 490/02, Wasnal).

Lower dentition: lI_3 (GCUPC 1151/12, Dhok Bun Amir Khatoon), lM_2 (GCUPC 673/09, Ratial), rM_2 (GCUPC 1168/12, Phadial), lM_3 (GCUPC 729/05, Wasnal).